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NUCLEAR DATA

A Collection of Experimental Values of Half-lives, Radiation Energies, Relative Isotopic Abundances, Nuclear Moments, and Cross Sections

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with assistance from
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Foreword

During the last decade identification and description of members of the nuclear population and determination of the characteristics of their society has proceeded at a continually accelerating pace. At the present moment the nuclear population numbers approximately 1,200 and is still growing. Knowledge of individual characteristics and of the laws of social behavior as reported in some 40 journals representing the work of dozens of laboratories is growing at an even more rapid rate.

The nuclear population is now so great and the sources of information so diverse that the active research worker in the field is in serious need of a periodic census to keep abreast of developments and guide his efforts into productive, nonduplicating investigation. In this year of our great decennial census, it seems only fitting that we should also enumerate and carefully describe the nuclear population.

This compilation of nuclear data is such a census. It is not the first. A number of careful compilations have appeared in the past and have proven their value. Although the increase in population and information indicates the desirability of a new count, this new compilation is based upon its predecessors as a firm foundation. But even this new census is not complete and exact. In common with any dynamic society, the nuclear population changes during the compilation. As the complexity of the society becomes more apparent, needs for further information are indicated. Any good census will clearly delineate this need and herein perhaps lies its major scientific value.

It therefore becomes a matter of judgment and arbitrary decision to select a cut-off date and say, "Enough is available to go ahead. We will proceed without awaiting further developments." The cut-off date has been set at January 1, 1950, although where possible some 1950 information has been included. To take account of subsequent developments, the format of the presentation has been selected to allow incorporation of new information which will be issued periodically as supplements.

To make the census useful as a generator of new investigations and as a critique of the validity of existing reports similar information from different sources is presented. This information is often conflicting but no attempt has been made to select "best values." On the contrary, discrepancies are emphasized and pointed up so that they may serve as a stimulus for new work.

The compilers are quite conscious of inconsistencies and possible errors and omissions in the table. Its weaknesses and shortcomings will promptly become evident to many active workers who are urged and invited to contribute to future improvements. The compilers hope that, with criticism, suggestions, and information regarding errors from many sources, they will be able to produce subsequent editions which will better fill the needs of all workers in the nuclear field.

Grateful acknowledgment of the help of many scientists who have already given freely of their time is made below. Direct financial assistance from the Atomic Energy Commission has made possible the great amount of work necessary to bring the compilation to its present state.

Washington, D. C., May 1950. E. U. Condon, *Director*.

Preface

The Nuclear Data Group of the National Bureau of Standards has had the most generous assistance from many groups and individuals in collecting the data presented here, in checking them, and in planning the method of presentation. The Bureau group assumes, of course, the final responsibility for the accuracy of the material and for its editing, but it would like to make grateful acknowledgment of the invaluable assistance which it has received.

Both the Oak Ridge National Laboratory and the Brookhaven National Laboratory supported the nuclear data work from the beginning. A. M. Weinberg at Oak Ridge reorganized the Nuclear Data Committee there and made possible an integration of its current data collection program with the work of compilation undertaken at the Bureau.

Early plans for new nuclear tables were discussed at length with H. H. Goldsmith of the Information Division of the Brookhaven National Laboratory. Dr. Goldsmith immediately enlisted the interest of Gerhart Friedlander of the Brookhaven Chemistry Division and the two spent a great deal of time in helping to map out the work as a whole and in collecting and reviewing the data for a number of elements. Dr. Friedlander continued his help after the untimely death of Dr. Goldsmith and gave a meticulous check to Bureau work on regions of the periodic table with which he is especially familiar.

The Brookhaven Information Division encouraged other work in data collection and analysis by members of the Brookhaven Laboratory with the resultant preparation of reports* by H. L. Poss, D. E. Alburger and E. M. Hafner, and W. F. Hornyak. These reports have been of the greatest help to the compilers of the present table. Ways in which they have been used are discussed in detail in the section of explanation.

Dr. Hornyak gave a good deal of thought to possible ways for presenting all the data for the light nuclei in the present compilation. It was finally decided, however, to limit the material used, at least in this edition, to the radioactivity data and the bare level diagrams. The latter were kindly supplied by Dr. Hornyak from the data available in March 1950. Detailed discussion of the nuclear information furnished by light nuclei reactions has been given in previous summaries* of Lauritsen and Hornyak and will be extended and brought up to date in a forthcoming review paper* by Hornyak, Lauritsen, and Morrison. It is hoped that in the future ways of presenting this material in some convenient tabular form will be devised.

Members of the Nuclear Chemistry Group of the Laboratory for Nuclear Science and Engineering of the Massachusetts Institute of Technology very kindly cross-checked with the Bureau staff the data on the fission products. Professor Coryell of this group, an editor of Volume 9, Division IV, of the National Nuclear Energy Series, which will contain Manhattan Project papers on fission product work, made it possible for the Bureau group to give references to papers in this volume rather than to old and generally unavailable Metallurgical Laboratory reports. Those to whom the Bureau group is particularly indebted in addition to Professor Coryell are Ronald A. Brightsen, and Arthur Y. Sakakura.

Several of the chemists at the University of California Radiation Laboratory went over most of the data on the artificially produced heavy nuclei with a member of the Bureau staff and later sent lists of their most recent results. Special thanks are due to I. Perlman, G. T. Seaborg, E. K. Hyde, A. Ghiorso, and D. H. Templeton.

*Complete reference is given in the list of other compilations.

In its search for the older data the Bureau group has made extensive use of a number of other tables and compilations. These are listed on a separate page at the beginning of the reference section. In the work of collecting nuclear data reported since January 1949, the Bureau staff has had the assistance of two groups, the Nuclear Data Committee of the Oak Ridge National Laboratory already mentioned, which has sent in unclassified or declassified items appearing in AEC reports, and the National Bureau of Standards Nuclear Data Readers who have abstracted papers in the open literature. The members of the first group are Herbert Pomerance, chairman, N. M. Dismuke, F. K. McGowan, O. E. Myers, R. W. Stoughton, and H. Zeldes, all of the Oak Ridge National Laboratory. The members of the second group are U. Fano, National Bureau of Standards; W. Faust, Naval Research Laboratory; R. D. Huntoon, National Bureau of Standards; W. Koski, The Johns Hopkins University; F. N. D. Kurie, Naval Research Laboratory; W. B. Mann, British Embassy; G. G. Manov, Atomic Energy Commission, Isotopes Division; G. Plass, The Johns Hopkins University; J. S. Smart, Naval Ordnance Laboratory; and J. H. Sreb, Naval Research Laboratory.

An advisory panel serving at the request of Dr. Condon has given generous assistance to the Bureau staff on general problems connected with the scope of the work and methods of presentation. Members of the panel are Charles D. Coryell and Martin Deutsch, Massachusetts Institute of Technology; Louis Hempleman, Massachusetts General Hospital; Maria Goeppert Mayer, University of Chicago; Harvey Brooks, Knolls Atomic Power Laboratory; and Eugene P. Wigner, Princeton University.

Other physicists and chemists who have given particular help include G. Scharff-Goldhaber and M. Goldhaber of the University of Illinois, J. J. Howland of Brookhaven National Laboratory, G. E. Boyd and B. H. Ketelle of the Oak Ridge National Laboratory, and J. R. Stehn of the Knolls Atomic Power Laboratory.

The Nuclear Data Group is much indebted to the Bureau librarians for cheerful assistance and to many Bureau colleagues for helpful discussions. In the jobs of compiling and checking it has had important temporary help from Edith Haggstrom Nagel, Irma Wachtel, Miriam Dodson, and Abraham Schwebel.

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EXPLANATION OF TABLE

1. General

In the following table an attempt has been made to list the more recent, measured values of some of the nuclear constants. The philosophy behind the compilation has been that it should be primarily a tool for active workers in the field of nuclear physics rather than a list of "best values." Therefore, several values for each quantity have been included when available, so that the extent of agreement is at once apparent and discrepancies which call for further experiment are emphasized.

Older results are left out when there are a number of newer ones all in fair agreement, but an attempt was made to give enough references in one way or another so that all the older work can easily be found either directly or through the references given in the papers cited.

In general, results are reported as given by the original experimenters. In cases where corrections have been suggested by later writers the corrected value is listed and the reference to the original work is followed by a reference in parentheses to the later paper. As a general rule significant figures have been kept until they are in doubt by ten or more according to the judgment of the experimenter.

Question marks placed after specific values and followed by a reference indicate doubt on the part of the experimenters as to the validity of the result. Question marks in place of charge or mass numbers in the headings for the boxes are used to call attention to the fact that there is very little evidence for the assignment given. When placed after level values they indicate that the evidence for the level is inconclusive or open to more than one interpretation.

References. The reference keys are usually of the type 48H11. The first two numbers indicate the year of publication of the paper. The following capital letter is the first letter of the surname of the senior author and the following numbers merely serial. When other compilations are given as references, special keys are used consisting entirely of letters after the figures for the year; e. g., 48HL. These special keys are included in the reference list before the usual listings. For example, 48HL is to be found just ahead of 48H1. There is also a list of compilations with their respective keys just ahead of the main reference list.

A number of keys have lower case rather than capital letters for the author's name; e. g., 50k2. These special designations are used for papers to appear in 1950 in Volume **9** of the National Nuclear Energy Series on the fission products. The work they describe was done during the war mainly at the Metallurgical Laboratory at the University of Chicago and until the publication of this volume will have been reported only in project documents which are generally unavailable.

No such special keys have been used for the papers collected in Volumes **14B** and **17B** of the National Nuclear Energy Series. This is the case because the listings in the Seaborg-Perlman* table made it possible to refer

*Complete reference is given in the list of other compilations.

to papers in both of these volumes in advance of their publication. In such instances the year appearing in the Seaborg-Perlman reference is the year appearing in the key unless the paper in question has also appeared in the Physical Review in which case the year of publication there is used.

Decay Schemes.—Decay schemes have been drawn whenever the data on radioactivity are sufficiently self-consistent. Conventions adopted are:

Full single arrow slanting to the right for β^- emission ↘
Full single arrow slanting to the left for β^+ emission ↙
Dashed single arrow slanting to the left for decay by electron capture
Full double arrow slanting to the left for α emission
Wiggly vertical arrow for γ emission

Spin values have been attached to levels when they have been measured directly. Where there is indirect evidence for spin values from studies of angular correlation or gamma ray conversion coefficients, this evidence is noted below the decay scheme.

Very Light Nuclei, Z=0—10. The data for the very light nuclei are treated as elsewhere in the table with the exception of data relating to energy levels. Energy level values are listed or shown in diagrams, but the nuclear reaction data which support the level values are not reported in detail. Reference is made instead to summary articles and reviews of Hornyak and Lauritsen (48HL), Lauritsen (48Lau), and Hornyak, Lauritsen, and Morrison (50HLM) which contain comparisons and discussions of the data and pertinent references to the original literature. As mentioned before Dr. W. F. Hornyak has given considerable thought to ways of organizing the data for very light nuclei in tabular form. Some work along lines suggested by him was started, but the job proved to be so big that its completion would have delayed the appearance of this table for some months. It was therefore temporarily abandoned. The energy level values given here are those considered best by Dr. Hornyak in March 1950, and were very kindly communicated by him in advance of their publication elsewhere.

Mass values have not been included. A new set of masses for nuclei through A^{41} is given in the *Isotopic Report* of Mattauch and Flammersfeld* but the details of the calculations have not yet been published. An older set of values is included in Bethe's *Elementary Nuclear Theory.**

Light Nuclei, $Z=10$–20. Information about the energy levels of nuclei with charge between 10 and 20 has been carefully organized by D. E. Alburger and E. M. Hafner (49AH). Their selection of level values has been used extensively in the present compilation. Such use is indicated by placing the reference key 49AH on the line marked "Levels." In the Z=10–20 region, however, direct reference is made to the original literature on nuclear reactions, either under methods of production or under resonances. Q values and thresholds are given when measured.

Fission Products. The special keys, such as 50k2, which are used for a number of references in this region have been explained in the section headed References.

Under the methods of production the designation "Fission" means that the nucleus in question has been identified as the fission product of some heavy nucleus. No attempt has been made to distinguish between different kinds of fission, since in this compilation methods of production are given primarily to help in making mass assignments. Most of the direct references are to studies of the fission of U^{235}. When the Seaborg-Perlman table lists other modes of fission as methods of production, this fact is noted by including the reference key for that table, 48SP. Reference is also made to papers on the fiission of other heavy nuclei which have appeared since the Seaborg-Perlman table was published. Fission yields have not been given. It is now known that the yield depends not only on the identity of the fissioning nucleus but also on its excitation energy. The yield curve for the slow neutron fission of U^{235} is readily available in the Plutonium Project Report, Nuclei Formed in Fission (46PP).

Very Heavy Nuclei. When observed, α activity has been indicated in about the middle of the data box for both β stable and β active nuclei. In cases of β-α branching, percentages given to the left of the α energies are percentages of disintegrations in which the α's in question have been found; those to the right are percentages of the total number of α particles.

For data on new, artificially produced nuclei of very heavy elements the compilers are much indebted to the Seaborg-Perlman group at the University of California Radiation Laboratory. An effort was made to tabulate all the important results for the naturally occurring radioactivities but it is realized that a complete coverage has not been made of the voluminous literature in this field. It is hoped that those who have made detailed studies will point out important omissions so that a better job can be done in a revised edition. References have been omitted for the well known genetic relationships in the naturally occurring families. Neutron cross sections have been omitted for elements heavier than bismuth.

Isomerism. When an excited state of a particular nucleus has a half-life of more than one second, it is treated as a distinct radioactive species and given a separate box just to the left of the box containing the proper-

*Complete reference is given in the list of other compilations.

ties of the ground state. Both boxes have a common heading $_ZA_N$. If both isomers are active the two half-lives are indicated in the usual place and are designated as τ_1 and τ_2. In cases of triple isomerism the treatment is similar.

When the half-life of an upper state is less than one second, this half-life is indicated on the decay scheme and is listed again in connection with the γ-ray whose delay has been noted.

2. Neutron Cross Sections for Natural Elements

Absorption, scattering, and total cross sections have been measured for a number of elements which in many cases consist of several stable isotopes. Such cross sections are listed in the first box under each element. Even when an element has only one stable isotope, the above cross sections are given first for the sake of uniformity. Cross sections which have been assigned to a certain isotope from activation results or other measurements are always listed under that particular isotope. Therefore in the case of monoisotopic elements, such as Al, both the box for the 'natural element' and the box for Al^{27} should be consulted for complete cross section information.

An attempt has been made to list all measurements of cross sections which have been made as a function of neutron energy and for which cross section graphs are available. It did not seem feasible, however, to list all measured neutron cross section values. A fairly comprehensive job of this kind was done in 1947 and revised in 1948 by K. Way and G. Haines, 48WH. The policy here has been to list those values in 48WH which seem to be the most reliable and to add any more recent results. Occasionally an averaged value from several measurements listed in 48WH is given. The reference key for such a value is (48WH). The cooperation of several experimenters has also made it possible to include a number of values which are still unpublished or are contained only in Atomic Energy Commission reports. More detailed mention of such results is made in the following paragraphs.

σ_s Coh and σ_s Bound, Coherent and Bound Scattering Cross Sections. The values listed for these scattering cross sections are all from the recent neutron diffraction work of C. G. Shull and E. O. Wollan of the Oak Ridge National Laboratory, who very kindly supplied a list of their results. The experimental methods used are described in detail in two papers listed under the reference 49S12. Definitions of the terms will be found in the explanations for the abbreviations used in this table as well as in the papers just mentioned. The monochromatic neutrons employed had a wave length of 1.057 A ($E_n \sim 0.08$ ev) but since these cross sections are believed to be practically independent of neutron energy in the low energy region, no neutron energy value is associated with them. The values for σ_S bound are not all derived from new work but represent the best values according to Shull and Wollan for these quantities in the light of all results.

σ_a, Absorption Cross Section. For the most part the values given for the absorption cross sections are from the results of oscillator measurements made at the Oak Ridge pile by H. S. Pomerance and co-workers (49P3) and at the Argonne pile by S. P. Harris and his collaborators (49H2). The Oak Ridge workers measured periodic fluctuations in neutron density in the pile shield caused by the oscillating motion of an absorbing sample. The measurements were made relative to gold whose absorption cross section at 0.025 ev was taken as 95 barns. Values at 0.025 ev were calculated assuming a 1/v dependence.

The Argonne results are not directly comparable to the Oak Ridge values and strictly speaking should not have been listed under neutron energies of 0.025 ev. They are oscillator values for pile neutrons and consist of the values at 0.025 ev plus a small amount of the resonance integral. The apparatus was calibrated using 710 barns as the absorption value for boron at a neutron energy of 0.025 ev.

σ_s, Scattering Cross Section. The values listed here are those found from direct measurement of this quantity. Additional light on the best value of σ_s will be found from the value for σ_s *bound* or analysis of the total neutron cross section curves.

σ_t, Total Cross Section. The total (absorption plus scattering) cross section is measured by transmission methods. Since transmission curves are now available for most elements, the values for $E_n = 0.025$ ev have been read off the graphs.

Resonances. Information on neutron resonances is given when available in terms of the Breit-Wigner constants σ_o, E_o, and Γ. These symbols are defined in the list of abbreviations. Where assignment of a resonance to a particular isotope has been made this fact is indicated. However, the value of σ_o given is that found for the natural element.

Fast Neutron σ's. When available a value of σ_t for some neutron energy of the order of 1 Mev or more is listed chiefly for purposes of orientation. Other values will be found from the graphs listed or in 48WH.

Graphs Available. Cross section graphs have been listed even if two or more happen to cover the same neutron energy region since they often include different results. A new attempt to synthesize all cross section data capable of being plotted has been made by R. K. Adair (50Ad), who very kindly supplied advance copies of his drawings. Since his report is still unpublished the best plan seemed to be to refer to the older papers as well as this forthcoming one.

3. β and γ Stable Nuclei

$_{Z}A_{N}$	
Relative Abundance in %	Reference
I (Spin in units of $\hbar$)	Reference
μ (Magnetic moment in nuclear magnetons)	Reference
q (Electric quadrupole moment in barns)	Reference
Energy levels in Mev from	β decay Reaction
Reactions which show resonances in which $_{Z}A_{N}$ is the compound nucleus	
σ's	
Cross sections in barns or millibarns (mb)	Reference
Methods of production when these give information about levels or binding energies	Reference

β and γ Stability. A heavy black line at the top of a box denotes stability against β decay to a different nucleus and against γ decay to a lower state of the same nucleus. Doubtful cases have been marked with dashed lines. In the region of natural α activity assignments of β stability have been made in accordance with the rules which apply in other regions of the periodic table and the most stable charge numbers Z_A. The values for Z_A have been taken from the stability line of the Sullivan chart.* A discussion of other possibilities is given by S. Nordstrom and by Perlman, Ghiorso, and Seaborg in recent papers.**

Relative Abundances. When variations in relative abundances have been observed in materials from different sources, a note of the fact is made and reference given to papers in which measurements of the variations are reported.

Nuclear Moments. For values of the nuclear moments, the present compilers have leaned very heavily on the recent collection of H. L. Poss (49Po). Poss's values of the magnetic and electric quadruple moments which were calculated from the original data in a uniform way have been given with the reference 49Po whenever available. On the following lines the experimental methods used are listed by means of abbreviations, and literature references to the experimental work are given. In the case of only one experimental value the experimental reference is given first followed by 49Po in parentheses. Poss's values are based on a proton moment of 2.7934 nuclear magnetons.

Energy Levels. An attempt has been made to list under each nucleus the energy levels of that nucleus which can be deduced from the α, β, or γ decay of a parent or from resonances or particle groups in nuclear reactions. In the first case the parent nucleus is given in the usual place for a reference, and further information will be found under that nucleus. In the second case the reaction is given as a reference. Literature references are given just below the list of levels when the nucleus in question is the compound nucleus formed in the reaction and under the methods of production when it is the end product.

Neutron and Charged Particle Cross Sections. Cross sections given in the box for a particular isotope are those which have been definitely assigned to the isotope in question and are isotopic rather than atomic values; i. e., values per atom of the isotope rather than per atom of the natural element. In all cases the nucleus $_{Z}A_{N}$ is the target nucleus. Within the parentheses the energy of the bombarding particle and the symbol for the particle appear before the comma, and the symbol for the emitted particle after the comma. Following the parentheses the half-life and chemical symbol of the active product formed, if any, are given. When no active product is indicated, the cross section given has been obtained by an absorption method in which the disappearance of neutrons rather than the appearance of radioactivity is measured. In most cases the reaction will be (n, γ) but other possibilities are not excluded. The entries under σ's for Ag^{107} may serve for illustrations of the general scheme of abbreviation:

(th n, γ)2.3^{m}Ag **44** 47S33

means that the cross section of Ag^{107} for the production of 2.3^{m}Ag by an (n,γ) reaction with thermal neutrons has been found to be 44 barns by 47S33.

Cross section measurements with slow neutrons are usually made relative to the value for some large absorber whose cross section is known from transmission measurements and which has been found to vary as $1/v$ where v is the neutron velocity. The value found for the neutron distribution used is then converted to a value for monoenergetic neutrons of energy 0.025 ev under the assumption that the new cross section also has a 1/v dependence and this converted value is reported as the thermal cross section. Neutron energies for such cross sections are listed as "th" (thermal) rather than as 0.025 ev to call attention to the fact that measurements were not actually made at a specific energy. If a cross section does vary as 1/v its average value for any neutron distribution can be found from the relation

$$\bar{\sigma} = \sigma\ (0.025\text{ev})\ 2200/\bar{v}$$

where $\bar{v}$ is the average neutron velocity in meters per second in the distribution in question.

*Complete reference is given in the list of other compilations.

**S. Nordstrom, Zeits. f. Naturforsch. 5a, 6 (1950). I. Perlman, A. Ghiorso, G. T. Seaborg, Phys. Rev. 77, 26 (1950).

The isotopic activation cross sections reported by an experimenter depend upon the values of the half-life and relative abundance used in his calculations. Since most of the activation measurements are good only to about 20 percent, corrections have not been made in this table for more recent values of either secondary quantity. If a correction has been made for a new value of a cross section taken as a standard, a note of this fact is made with the reference.

The next line in the Ag^{107} cross sections

(th n, γ)	**30**	48H38

means that a sample of Ag^{107} separated electromagnetically from Ag^{109} has been found to have an absorption cross section of 30 barns for neutrons of 0.025 ev by methods similar to those just described. This result is not in good agreement with the activation value. The discrepancy is probably due to the difficulties of activation measurements.

The next line

($\sim$1Mev n, γ)2.3^{m}Ag	**0.13**	49H5

shows that the Ag^{107} activation cross section for neutrons of $\sim$1 Mev energy is 0.13 barns according to 49H5.

The following entry

(16Mev e^-, e^-n)24.3^{m}Ag	**5.4×10^{-4}**	48S3

means that the cross section of Ag^{107} for the production of the 24.3^{m}Ag by means of 16 Mev electrons has been found to be 5.4×10^{-4} barns by 48S3.

Finally, under Graphs Available,

σ(n,γ)2.3^{m}Ag	0.003–6Mev	46L7, 47GIF, 50Ad

is intended to convey the information that the activation cross section for production of 2.3^{m}Ag by an (n,γ) reaction has been measured for various values of the neutron energy from 0.003 Mev to 6 Mev by 46L7. A graph of the results is given in the compilations 47GIF and 50Ad as well as in the original paper.

Only the more recent neutron cross section values are included. Older results are listed in the cross section compilation of K. Way and G. Haines (48WH).

It was originally intended to include all values of charged particle cross sections, since not many of these are known and they have not been collected elsewhere. However, when the compilation was partially completed, it was found that some had been missed, especially those contained in project documents. The difficulty of making the collection complete at that time seemed monumental. It was decided, however, to leave those which had already been listed since they may help to orient readers in the order of magnitude of the results to be expected from possibly unfamiliar types of irradiations and to give a feeling for the relative probability of different types of reactions.

Methods of Production. These are given for stable nuclei only when Q values have been measured. The different Q values for a given reaction found by a particular experimenter are listed on the same line separated by commas.

4. β or γ Active Nuclei

$_ZA_N$		
τ	Half-life	Reference
K capture if observed		Reference
β^+ or β^- percentages of β groups	Maximum energy Method	Reference
γ	Energy Method Conversion coefficients	Reference
X-rays		Reference
Producing reaction		Reference
	Chemical separation Cross section, yield, or excitation function observed	
descendant of		Reference
predecessor of		Reference

Degree of Certainty Symbols. Symbols indicating degree of certainty of the mass and charge assignments of radioactive nuclei are not included. The symbols commonly used for this purpose are A, B, C, etc. It was felt that while such symbols may serve a useful purpose on charts or in shorter compilations they are out of place in a table where the information on which they are based is immediately available. Moreover, some symbols have in the past engendered false complacency and discouraged experiments which should have been tried. It seemed safer and more stimulating to let the past work speak for itself and call forth all possible doubt and criticism.

Relative Abundances and Half-lives. In the few cases where β active nuclei are found in nature, their abundances relative to other isotopes of the element to which they belong are given first. In all other cases a list of the measured values of the half-life heads the data. To avoid confusion with other abbreviations, the symbols for the time units (s, m, h, d, y) are used as superscripts throughout the table. Half-lives are generally given in the units which have been most commonly used. However, values exceeding 100^s or 100^m have been given in terms of the next larger unit.

K Capture. If there is evidence for decay by K or L electron capture this fact is next indicated. The X-rays observed are listed after the γ-rays so the extent to which they support the indication of K capture is easily ascertained.

β-Rays. Information about β^+ or β^- emission follows. The maximum energy of the β-rays and the method of measurement are given wherever available in the center column. All energies are in Mev as elsewhere in the table. If partial β-ray spectra have been observed, the various endpoint energies and estimated percentages are given. The notation "complex" indicates that the experimenter has found some evidence for more than one β-ray, but has not been able to resolve the β groups; "simple" means that he has looked specifically and found no evidence for more than one group. The appearance of the β symbol without an energy value means that the radiation has been detected but not measured quantitatively.

γ-Rays. The γ-rays are listed with abbreviations for the methods of measurement and values of the conversion coefficients when these have been reported. Annihilation radiation is not specifically noted but should be assumed as present wherever there are positrons. If conversion has been noted but no conversion coefficient measured, this fact is shown either by explicit mention of the presence of e^- or by the fact that the γ-ray energy was found from the measurement of the energy of conversion electrons. The two method abbreviations "sc" and "ac", mean respectively, spectrometer and absorption measurements by means of conversion electrons. Conversion electrons not clearly identified with particular γ-rays are listed separately. X-rays observed are identified according to X-ray terminology (Cs K_α, etc.) when the experiment has made this possible. When doubt of identity still exists, some indication of the energy observed is given whenever possible.

Methods of Production. Nuclear reactions which produce a given radioactive nucleus as end product are listed in the lower part of the box, (Sn-γ-n, Sb-d-p, etc.). If isotopically enriched material has been used to establish a particular reaction, this fact is indicated by putting the target mass number after the chemical symbol (Sb ^{123}-n-γ).

The policy has been to list those reactions that help to establish the mass of the product nucleus or its neighbors rather than to put down all reactions by which it has ever been produced. For this reason note of production by spallation reactions is generally omitted. The papers on fission which are cited deal chiefly with the slow fission of U^{235}. When references to production in other fission processes are given in the Seaborg-Perlman table this fact is noted by including the key 48SP. If a mass spectrograph identification of the product of a reaction has been made the symbols "ms" follow the reaction. If the experimenters report that a chemical separation of the product element was made after the nuclear reaction had taken place, the abbreviation "chem" follows the reaction. In many cases, especially where the work is described in an abstract only, it seems probable that chemistry was done but since no specific mention of the fact was made, "chem" could not be included. The best policy would probably be to put down "chem" only when the chemistry performed is described in some detail but if this policy had been applied to past work, in many cases it would not be apparent that the chemical identity of the product is felt to be well established.

If the cross section or excitation function for any reaction listed has been measured or if the reaction yield is known the abbreviations "σ", "f", or "yield" follow "chem". In the case of slow neutron cross sections, the actual values reported will be found under the data on the target nucleus. It was originally intended to include all other cross sections but, as noted elsewhere, this plan was only partially carried out. Reaction energies, Q, or threshold energies when available are also recorded just under the reaction. The maximum energy of the capture γ's found in (n, γ) reactions is listed as E_γ (max).

No attempt has been made to give references to all the papers in which a particular reaction is reported as Mattauch and Flammersfeld have done. The policy adopted here was to list only the more recent papers reporting the reactions that refer in turn to a large number of previous papers also describing the same reaction. By using these papers as secondary sources it is believed that most of the references for a given reaction can be quickly accumulated.

Genetic Relationships. At the very bottom of the box, information is given about genetic relationships with the help of the abbreviation "p" for predecessor of, and "d" for descendant of. The predecessors or descendants are identified by means of their half-lives and chemical symbols. In the heavy element region where there is possible confusion between α and β decay their probable mass assignments are also given.

5. Abbreviations

All energies are given in Mev unless otherwise stated.
All cross sections are given in barns (10^{-24} cm^2) unless otherwise stated.

a	Measurement by absorption method
a $\beta\gamma$	measurement by absorption of β's in coincidence with γ's
ac	measurement by absorption of conversion electrons
a coin	measurement by placing absorbers between counters in coincidence
α	(1) alpha particles; (2) total γ-ray conversion coefficient defined as ratio of total number of conversion electrons to number of γ-rays, i. e. N_e/N_γ. If $c=N_e/(N_e+N_\gamma)$, $\alpha=c/(1-c)$.

$\alpha_{K,L,M}$	γ-ray conversion coefficient for electrons ejected from the K, L, M, shell
B	band spectra method
β^-	negative beta particles
β^+	positive beta particles
cc	measurement by cloud chamber
ce	crystal effects
chem	chemical separation of product made
d	(1) deuteron; (2) descendant of; (3) days, when used as superscript
D	deuterium
e or e^-	electron
E_0	neutron resonance energy, usually in ev
E_β, E_γ, etc.	energy of β-ray, energy of γ-ray, etc.
$\bar{E}$	average energy
ev	electron volts
f	excitation function determined
γ	gamma rays
Γ	resonance half-width (the whole width at half-maximum), usually in ev. Breit-Wigner formula: $\sigma=[\sigma_0\Gamma^2(E_0/E)^{1/2}]/[4(E_0-E)^2+\Gamma^2]$
γn	measurement by means of photo neutron detection
h	hours, when used as superscript
I	(1) spin in units of $\hbar$; (2) nuclear induction method
ic	measurement by ionization chamber
IT	isomeric transition
K	electron capture from the K shell
K/L	α_K/α_L
kev	thousand electron volts
KU	β-ray end point found using Konopinski-Uhlenbeck theory
L/(M+N)	$\alpha_L/(\alpha_M+\alpha_N)$
L capture	electron capture from the L shell
L/M	α_L/α_M
m	minutes, when used as superscript
M	molecular or atomic beam resonance method
mb	millibarns
Mev	million electron volts
Mic	microwave method
ms	mass spectroscopic identification of mass number
μ	magnetic moment in units of nuclear magnetons
μs	microseconds
n	neutron
N	measurement by means of nuclear scattering experiments
p	(1) proton; (2) predecessor of
P	polarization of resonance radiation method
pc	measurement by means of proportional counter
q	electric quadrupole moment in units of barns
Q	reaction energy in Mev
rel	relative
s	(1) spectrometer measurement by means of secondary electrons; (2) seconds, when used as superscript
S	measurement by means of atomic spectra
$s\beta\gamma$	spectrometer measurement of β's in coincidence with γ's
sc	spectrometer measurement by means of conversion electrons
scin	measurement by means of scintillation counter
σ	cross section in barns
σ_0	cross section at resonance energy, E_0. See Γ.
σ_a	absorption cross section in barns
σ_{ac}	activation cross section in barns
σ_{eff}	effective cross section in barns
σ_s	scattering cross section in barns
σ_s bound	bound scattering cross section or $4\pi(p_1f_1^2+p_2f_2^2+ - - -)$ where the f's are the bound scattering lengths and the p's are the relative isotopic abundances. See 49S12.
σ_s coh	coherent scattering cross section or $4\pi(p_1f_1+p_2f_2+ - - -)^2$
σ_t	total cross section in barns
t	triton
th	thermal
τ	half-life in units indicated
wt	weight
y	years, when used as superscript
Z	method of zero moments

1. Alphabetical Index to Elements

Element	Symbol	Z	Page
Actinium	Ac	89	258
Aluminum	Al	13	23
Americium	Am	95	271
Antimony	Sb	51	137
Argon	A	18	32
Arsenic	As	33	70
Astatine	At	85	249
Barium	Ba	56	164
Berkelium	Bk	97	273
Beryllium	Be	4	5
Bismuth	Bi	83	241
Boron	B	5	7
Bromine	Br	35	77
Cadmium	Cd	48	124
Calcium	Ca	20	37
Californium	Cf	98	274
Carbon	C	6	9
Cerium	Ce	58	171
Cesium	Cs	55	159
Chlorine	Cl	17	30
Chromium	Cr	24	47
Cobalt	Co	27	53
Copper	Cu	29	58
Curium	Cm	96	272
Dysprosium	Dy	66	194
Emanation	Em	86	252
Erbium	Er	68	199
Europium	Eu	63	185
Fluorine	F	9	15
Francium	Fr	87	254
Gadolinium	Gd	64	188
Gallium	Ga	31	64
Germanium	Ge	32	67
Gold	Au	79	227
Hafnium	Hf	72	210
Helium	He	2	3
Holmium	Ho	67	197
Hydrogen	H	1	2
Indium	In	49	128
Iodine	I	53	148
Iridium	Ir	77	223
Iron	Fe	26	51
Krypton	Kr	36	81
Lanthanum	La	57	168
Lead	Pb	82	237
Lithium	Li	3	4
Lutetium	Lu	71	207
Magnesium	Mg	12	21
Manganese	Mn	25	49
Mercury	Hg	80	231
Molybdenum	Mo	42	102
Neptunium	Np	93	267
Neodymium	Nd	60	176
Neon	Ne	10	17
Neutron	n	0	1
Nickel	Ni	28	56
Niobium (Columbium)	Nb	41	99
Nitrogen	N	7	11
Osmium	Os	76	221
Oxygen	O	8	13
Palladium	Pd	46	116
Phosphorus	P	15	26
Platinum	Pt	78	225
Plutonium	Pu	94	269
Polonium	Po	84	246
Potassium	K	19	34
Praseodymium	Pr	59	174
Promethium	Pm	61	179
Protactinium	Pa	91	263
Radium	Ra	88	256
Rhenium	Re	75	218
Rhodium	Rh	45	113
Rubidium	Rb	37	85
Ruthenium	Ru	44	110
Samarium	Sm	62	182
Scandium	Sc	21	40
Selenium	Se	34	73
Silicon	Si	14	25
Silver	Ag	47	119
Sodium	Na	11	18
Strontium	Sr	38	89
Sulphur	S	16	28
Tantalum	Ta	73	213
Technetium	Tc	43	106
Tellurium	Te	52	142
Terbium	Tb	65	191
Thallium	Tl	81	234
Thorium	Th	90	260
Thulium	Tm	69	202
Tin	Sn	50	133
Titanium	Ti	22	43
Uranium	U	92	265
Vanadium	V	23	45
Wolfram (Tungsten)	W	74	215
Xenon	Xe	54	154
Ytterbium	Yb	70	204
Yttrium	Y	39	92
Zinc	Zn	30	61
Zirconium	Zr	40	96

2. Atomic Number Index to Elements

Element	Symbol	Z	Page
Neutron	n	0	1
Hydrogen	H	1	2
Helium	He	2	3
Lithium	Li	3	4
Beryllium	Be	4	5
Boron	B	5	7
Carbon	C	6	9
Nitrogen	N	7	11
Oxygen	O	8	13
Fluorine	F	9	15
Neon	Ne	10	17
Sodium	Na	11	18
Magnesium	Mg	12	21
Aluminum	Al	13	23
Silicon	Si	14	25
Phosphorus	P	15	26
Sulphur	S	16	28
Chlorine	Cl	17	30
Argon	A	18	32
Potassium	K	19	34
Calcium	Ca	20	37
Scandium	Sc	21	40
Titanium	Ti	22	43
Vanadium	V	23	45
Chromium	Cr	24	47
Manganese	Mn	25	49
Iron	Fe	26	51
Cobalt	Co	27	53
Nickel	Ni	28	56
Copper	Cu	29	58
Zinc	Zn	30	61
Gallium	Ga	31	64
Germanium	Ge	32	67
Arsenic	As	33	70
Selenium	Se	34	73
Bromine	Br	35	77
Krypton	Kr	36	81
Rubidium	Rb	37	85
Strontium	Sr	38	89
Yttrium	Y	39	92
Zirconium	Zr	40	96
Niobium	Nb	41	99
Molybdenum	Mo	42	102
Technetium	Tc	43	106
Ruthenium	Ru	44	110
Rhodium	Rh	45	113
Palladium	Pd	46	116
Silver	Ag	47	119
Cadmium	Cd	48	124
Indium	In	49	128
Tin	Sn	50	133
Antimony	Sb	51	137
Tellurium	Te	52	142
Iodine	I	53	148
Xenon	Xe	54	154
Cesium	Cs	55	159
Barium	Ba	56	164
Lanthanum	La	57	168
Cerium	Ce	58	171
Praseodymium	Pr	59	174
Neodymium	Nd	60	176
Promethium	Pm	61	179
Samarium	Sm	62	182
Europium	Eu	63	185
Gadolinium	Gd	64	188
Terbium	Tb	65	191
Dysprosium	Dy	66	194
Holmium	Ho	67	197
Erbium	Er	68	199
Thulium	Tm	69	202
Ytterbium	Yb	70	204
Lutetium	Lu	71	207
Hafnium	Hf	72	210
Tantalum	Ta	73	213
Wolfram	W	74	215
Rhenium	Re	75	218
Osmium	Os	76	221
Iridium	Ir	77	223
Platinum	Pt	78	225
Gold	Au	79	227
Mercury	Hg	80	231
Thallium	Tl	81	234
Lead	Pb	82	237
Bismuth	Bi	83	241
Polonium	Po	84	246
Astatine	At	85	249
Emanation	Em	86	252
Francium	Fr	87	254
Radium	Ra	88	256
Actinium	Ac	89	258
Thorium	Th	90	260
Protactinium	Pa	91	263
Uranium	U	92	265
Neptunium	Np	93	267
Plutonium	Pu	94	269
Americium	Am	95	271
Curium	Cm	96	272
Berkelium	Bk	97	273
Californium	Cf	98	274

3. Index for Classical Radioactive Families

Thorium Family

Name	Z	Isotope	Page	Name	Z	Isotope	Page
Th	90	Th^{232}	261	ThA	84	Po^{216}	248
$MsTh_1$	88	Ra^{228}	257	ThB	82	Pb^{212}	240
$MsTh_2$	89	Ac^{228}	259	ThC	83	Bi^{212}	245
RdTh	90	Th^{228}	261	ThC′	84	Po^{212}	247
ThX	88	Ra^{224}	257	ThC″	81	Tl^{208}	236
Tn	86	Em^{220}	253	ThD	82	Pb^{208}	239

Uranium Family

UI	92	U^{238}	266	RaB	82	Pb^{214}	240
UX_1	90	Th^{234}	262	RaC	83	Bi^{214}	244
UX_2	91	Pa^{234}	264	RaC′	84	Po^{214}	248
UZ	91	Pa^{234}	264	RaC″	81	Tl^{210}	236
UII	92	U^{234}	266	RaD	82	Pb^{210}	239
Io	90	Th^{230}	261	RaE	83	Bi^{210}	243
Ra	88	Ra^{226}	257	RaF	84	Po^{210}	247
Rn	86	Em^{222}	253	RaG	82	Pb^{206}	238
RaA	84	Po^{218}	248				

Actinium Family

AcU	92	U^{235}	266	An	86	Em^{219}	253
UY	90	Th^{231}	261	AcA	84	Po^{215}	248
Pa	91	Pa^{231}	263	AcB	82	Pb^{211}	240
Ac	90	Ac^{227}	258	AcC	83	Bi^{211}	244
RdAc	90	Th^{227}	260	AcC′	84	Po^{211}	247
AcK	87	Fr^{223}	255	AcC″	81	Tl^{207}	235
AcX	88	Ra^{223}	256	AcD	82	Pb^{207}	238

	I 0 I	
	τ 10-30^{m} 50S6 9-18 50R2 I 1/2 N 37S9 μ -1.9135 49Po I 48B29, 47A10, 49R15 β^- 50S6 p 50R2, 50S6 D-γ-p 50HLM	

Neutron Cross Sections for Natural Element

σ_s coh	2.0	(-)	49S12
σ_s bound	80		49S12
$E_n = 0.025$ev			
σ_a	0.32		(48WH)
	0.33		48R13
	0.25		49H2
σ_t Value depends on H compound used			See graphs
List of thermal values for various compounds			48WH
Free proton value			
	20.36		49M4
	20.8 (theoretical)		47B28
$E_n = 1$Mev			
σ_t	4.2		49B48
			See graphs

Graphs Available

σ_t (H_2, H_2O, methane, ethane, propane, n-butane, cetane, ethylene, 1,3-butadiene)		
	0.003-100 ev	49M40
σ_t	0.03-23Mev	47GIF
	0.03-290Mev	50Ad
	0.8-1.6Mev	49L20
Other fast n references on graphs and in		48WH

I
I 0

	99.9844%		36H3
I	1/2	B	30H2, 29M1, 30C1
		SH*	27D1
μ	2.7926**		49H49
	1.4100** dyne cm/gauss		49T18
	1.52100** Bohr magnetons		49G11
	1.52106** Bohr magnetons		49T1

σ's

See natural element

* Specific heat measurements
** Diamagnetic correction for atomic hydrogen (41L3) applied

2
I I

	0.0156%		36H3
	0.015		39S19
σ_s coh	5.0	(+)	49S12
σ_s bound	7.4		49S12
$E_n = 0.025$ev			
σ_a (D_2O)	0.92mb*		47S38
σ_s (D_2O)	15.3*		46R9
σ_t (D_2O)	14.6*		See graphs

* per molecule

$E_n = 1$Mev		
σ_t	3.1	See graphs

Graphs Available

σ_t	0.005-40 ev	48R6, 47GIF
	0.35-14Mev	47GIF
	0.35-290Mev	50Ad
Other references on graphs and in		48WH

I	1	B	34M3
		OP*	34F2
μ	0.85761		49P0
		I	49S37, 49Z2, 47B29, 47R8, 47B30
		M	39K12
q	0.00273	M	40K10

* ortho-para conversion

3
I 2

τ	12.5^y		49J4
	12.1		47N1
	10.7		47G8
I	1/2	B	49D31
		I	47B31
μ	2.9795		49P0
		I	47A9, 47B32
β^-	0.0189	pc	49H1
	0.0180-0.0186	pc	49C8
	0.0180	a	49G7
	0.0170	cc	49B22
$\overline{E_\beta}$	5.69kev		49J4
	5.64		48H51
calorimetric measurements			
No γ			46G14
D-n-γ			50HLM
He^3-n-p			50HLM
D-d-p			50HLM
Li-n-α			48HL, 48Lau
Be-d-t			48HL, 48Lau

889592 O - 50 - 2

Neutron Cross Sections for Natural Element	3 2 1	4 2 2
$E_n = 0.025$ev σ_s 1.55 50H5	Atmospheric Value: 1.3×10^{-4}% 49C9,47F1 1.2×10^{-4} 48A7 Wide variations in well and mineral values 49C9,48A7 I 1/2 B 49D24 μ (-)2.128 I 49A11 Negative sign not verified σ's (th n,p)H^3 5040 49C10 5100 49K17 3700 49B32 Graphs Available σ(np) 0.001-0.03ev 49K17	~100% 47F1 I 0 B 29M1 N 31B1
Graphs Available σ_s 0.6-1.6Mev 47K13,47GIF σ_t 0.04-6.4Mev 49B48 Only one peak observed 49B48 σ(elastic back scattering) 0.5-1.8Mev 40S11 0.5-4.3Mev 39S18		

5 2 3	6 2 4	
τ $\sim 2.4 \times 10^{-21}$s Calculated weighted mean from several experiments 50HLM He-d-p Li-d-α } 50HLM	τ 0.82s 48K13,49H24 0.85 46S5 0.87 47C15 0.89 46H17 β^- 3.23 s 50P1 3.7 a 48K13 3.5 a 49A2,46S5 No γ 48K13 Li-γ-p Li-n-p Be-n-α } 50HLM	

Neutron Cross Sections for Natural Element

σ_s coh	0.4	(-)	49S12
$E_n = 0.025$ev			
σ_a	67		49P3
	65		44F13
σ_t	70		44F13
	71		46H26
$E_n \sim 2.5$Mev			
σ_t	2.0		39A5
Other fast n values			48WH
Graphs Available			
σ_t	0.015-5ev		50Ad, 46H26, 47GIF
$\sigma(n,\alpha)$	0.04-1.8Mev		50Ad, 47GIF

5 (3 2)

H^2-He^3-α
He-p-p } 50HLM

6 (3 3)

	7.30%		48W9
	7.40		48I6
	7.40-7.46		47H27
I	1	M	40K9
		Z	37M6
μ	0.8221	M	49S37 (49K31)
$\frac{q(Li^6)}{q(Li^7)}$	$\leqslant 0.044$	M	49K30
Levels ?	~ 1.0		50HLM
	~ 3.0		
σ's			
σ_s coh	(+)	~ 6	49S12

By calculation from Li and Li^7

Large absorption cross section of element attributed to n,α reaction in this isotope 37LB

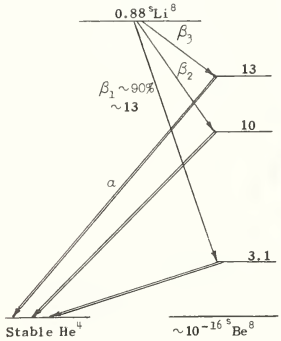
7 (3 4)

	92.70%		48W9
	92.60		48I6
	92.54-92.60		47H27
I	3/2	B	30H1
		S	32G3
		M	40K9
		Z	35F3
μ	3.2567		49Po
		I	49B7, 49Z2, 49S37
		M	41M8
q	$\sim +0.02$		49K29
Levels	0.477		48Lau, 48HL, 50HLM
	7.38		
σ's			
(th n,γ) $0.88^s Li$	33mb		47H6
	1mb		46P12
σ_s coh	(-)	0.8	49S12
σ_s bound		~ 2	49S12

8 (3 5)

τ	0.88^s		49B24, 47O2, 45H5, 37L1
	0.89		47H6

Proposed decay scheme 50H1



Maximum β energy ~ 13 50H1

β spectrum consistent with proposed decay scheme 50H1

β_1^- ~90%	~ 13	s	50H1
	12	a	47O2
	12	cc	37B1
$\beta_2^-, \beta_3^- \sim 10\%$			50H1

<5% of transitions to 4.8Mev γ emitting state of Be^8 50H1

No γ 37R3, 37B1

L1-d-p
L1-n-γ
Be-γ-p
B-n-α } 48HL, 48Lau

Neutron Cross Sections for Natural Element

σ_s coh	7.7	49S12
σ_s bound	7.5	49S12
	$E_n = 0.025$ev	
σ_a	0.009	47N5
	0.0085	47A8
	0.01	47H3
	$\leqslant$0.01	46M20
σ_s	6.9	37G1
σ_t	ce	See graphs

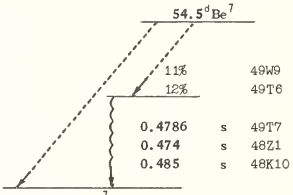
Values at other n energies 48WH, 49H16

Graphs Available

σ_t 0.004-10ev		47GIF, 47F12
0.5-4Mev		47A7
0.02-1.4Mev		50Ad, 49A8, 47GIF
1-300Mev		50Ad
$\sigma(n,\alpha)$ 1.7-4Mev		47A7

$^{7}_{4}$ ^{3}

τ	54.5^d	49B14
	52.9	49S20
	54.3	47B21
	53	40H14



11%		49W9
12%		49T6
0.4786	s	49T7
0.474	s	48Z1
0.485	s	48K10

Maximum energy of Li^7 recoils = 57ev 49S38

$\frac{\lambda(BeO)-\lambda(Be)}{\lambda(Be)} \sim -3\times10^{-4}$ 49S20

Level 0.43 50HLM

L1-p-γ
L1-d-n
L1-p-n
B-p-α
} 48HL, 48Lau

$^{8}_{4}$ ^{4}

τ	10^{-16}-10^{-17} s calculated value	37B5

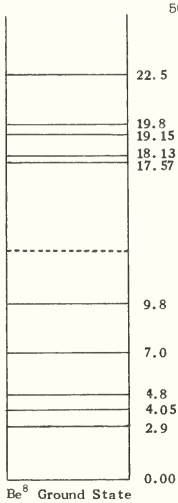
Mass difference in Mev

Be^8-2 He^4	0.103	48H2
	0.089	49T16

L1-p-γ
L1-d-n
Be-d-t
Be-p-d
Be-γ-n
B-d-α
B-n-t
Be-p-α
C-γ-α
} 48HL, 48Lau

d 0.88 s Li^8

Levels 50HLM



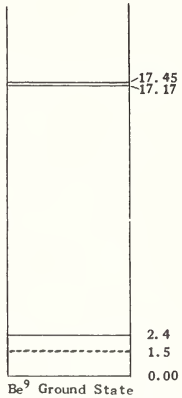
$^{9}_{4}$ 5

100% 37N2

I 3/2 ? S 41P4

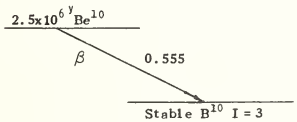
μ -1.1776 49Po
I 49C2, 49D25
M 39K9

Levels 50HLM



$^{10}_{4}$ 6

τ 2.5×10^{6} y 47M14
2.9×10^{6} 47H3



$\beta\gamma$ coincidences 49H20

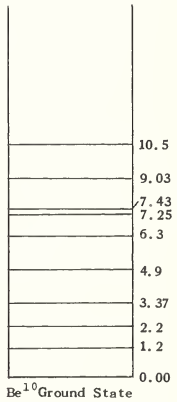
Probably no γ 47L3, 47M14, 49H19

Be-d-p ms 46P3
Be-n-γ
Be-d-p
B-n-p
Li-α-p
} 48HL, 48Lau

β^-			
0.555	s	50F1, 49W18
0.553	pc	49F12
0.560	s	50A2
0.560	a	47M14
0.530	scin	49B15
0.570	a	49H19

Straight line found from β spectrum when D_2 correction made 50A2, 49W18, 49F12

Levels 50HLM



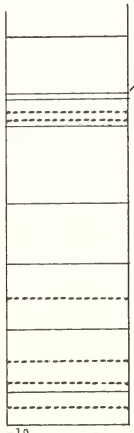
Neutron Cross Sections for Natural Element			9 / 5 4
	E_n = 0.025ev		
σ_a	718	49P3	
σ_t	702	47F13	
	708	46B31	
	737	47S36	
	745	46R8	
	Ep1-Cd		
σ_s	3.7	44A3	
	3.9	46D16	
	E_n = 1Mev		
σ_t	~1.7	See graphs	
	Graphs Available		
σ_t	0.01-1000ev	47S36, 47GIF	
	0.01-100ev	46R8	
See also		49H16	
	0.023-14Mev	50Ad, 47GIF	
	0.2-3Mev	46B32	
References on graphs and in 48WH			
$\sigma(n,\alpha)$	0.3-3.0Mev	47GIF, 50Ad	

10 / 5 5

18.83% 4611

I	3	Mic	48G20
μ	1.801		49Po
		I	49B7
		M	39M5
q	0.06	Mic	49G23
	σ's		
(th n,p)	<0.2		46B34
(~1Mev n,p)	3mb		47E4
σ_s(Ep1-Cd)	2.6		46D16
	Graph Available		
σ_t	0.2-3Mev		46B32

Levels 50HLM



B^{10} Ground State

σ's

Large absorption cross section of natural element attributed to n,α reaction in this isotope 37LB

$^{11}_{5}B_{6}$

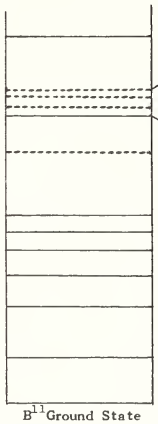
81.17% 46I1

I	3/2	Mic	48G20
μ	2.6886		49Po
		I	49Z2, 49B7, 49A12
		M	39M5
q	0.03	Mic	49G23

σ's

(th n,γ) 0.027^{s} B^{12} < 0.05		46B33
(~1Mev n,α)	0.085mb	46G31
σ_s (Epi-Cd)	4.0	46D16
Graph Available		
σ_t	0.2-3Mev	46B32

Levels 50HLM



B^{11} Ground State

$^{12}_{5}B_{7}$

τ	0.027^{S}		48J3
	0.022		39B6
β^-	13.43	s	50H1
	13.3	a	48H54
	12	cc	37B1
$\beta\gamma$ coincidences ?			49H41
β spectrum does not have simple allowed shape			50H1
Level	~1.5		50HLM

B-d-p
N-n-α
C-n-p
} 48HL, 48Lau

Neutron Cross Sections for Natural Element

σ_s coh	5.2	49S12
σ_s bound	5.2	49S12
	$E_n = 0.025$ev	
σ_a	~4.5mb	(48WH)
	4.9mb	47A8
	$E_n > 1$ev	
σ_t	4.70	49H18
	4.8	(48WH)
	Graphs Available	
σ_t	0.002-4ev ce	50Ad,47GIF
	0.02-300Mev	50Ad
	0.1-6Mev	47GIF
	0.6-1.6Mev	49L20

Fast n graphs in 50Ad and 47GIF based on many others. References on graphs and in 48WH

10
6 4

τ	19.1^s		49S25
β^+	2.2	a	49S25
γ	~1		49S25
B^{10}-p-n	chem		49S25
C-γ-2n ?			48P3

11
6 5

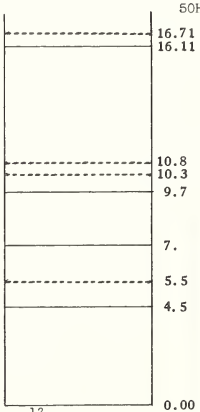
τ	20.35^m		41S11
	20.5		48P3,41S1
	20.0		44S3
β^+	0.970	s	44S3
	0.981	s	41T1
	0.95	cc	40D6
No $\beta\gamma$ coincidences			46S12
Level	2.0		50HLM
	4.5 ?		
	6.7 ?		
	10.1		
B-p-γ			48HL, 48Lau
B-d-n			
B-p-n			
C-n-2n			
N-p-α			

12
6 6

98.892% limestone 50N1
variations 41M7

I	0	B	48J21

Levels 50HLM

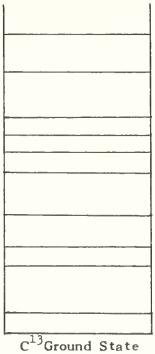


C^{12} Ground State

$^{13}_{6}C_{7}$

		1.108% limestone	50N1
		variations	41M7
I	1/2	B	48J21
μ	0.7023		49Po
		I	49P8
		M	41H14
σ's			
(th n,γ) 5,720^{y}C		~0.1	45L8
C-n-γ			
E_γ(max) = 4.9			49K32

Levels 50HLM



C^{13} Ground State

Also 22 levels found between 12.6 and 16.6 39F5,48HL

$^{14}_{6}C_{8}$

τ	5,720^y		49E5
	5,589		49J7
	6,400		48H26
	7,200		48Y2
	5,100		48N2
I	0	B	48J21
β^-	0.155	s	49F2,48B21
	0.154	s	47L8
	0.156	s	48C10
	0.154	a	47S26
	0.158	pc	49A3
No γ			41R5
Level	5.6		50HLM
	6.1		
σ's			
(th n,γ)		< 200	46E8
B-α-p			48HL, 48Lau
C-d-p			
N-n-p			
O-n-α			

889592 O - 50 - 3

Neutron Cross Sections for Natural Element

σ_s coh	4.6	49S12
σ_s bound	6-10	49S12
	E_n = 0.025ev	
σ_a	1.86	49P3
	1.45	49H2
σ_t	12.7	See graph
	E_n = 10-200ev	
σ_t	9.96	49M40
	Graphs Available	
σ_t	0.003-2000 ev	49M40
	0.3-3.4Mev	50Ad, 49B50
	0.03-90Mev	50Ad
	0.05-4Mev	47GIF
References on graphs and in 48WH		

12
7 5

τ	12.5×10^{-3} s		49A5
β^+	16.6	a	49A5
C-p-n			49A5

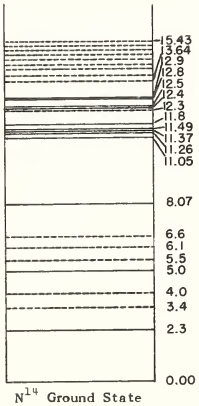
13
7 6

τ	10.1^m		45S3
	10.2		48C11
	9.93		39W4
β^+	1.24	s	45S3
	1.25	s	48C11
	1.22	s	41T1
No γ of 0.28Mev			46S12
No γ between 0.135 and 0.700Mev			47L4
Level	2.4		50HLM
	3.5		
C-p-n, B-d-n, C-d-n, C-p-γ, N-d-t			48HL, 48Lau
N-γ-n	relσ		48W13
threshold =	10.7		49M17
	11.1		45B12

14
7 7

	99.635%		50N1
	99.637		31U1
	99.620		35W1, 34V1
I	1	B	2801
		Mic	46D15, 46C10
μ	0.403	M	39K10 (49Po)
q	0.02	Mic	48T11, 49T17
σ's			
(th n,p)		1.75	49C10
		1.60	49B32
Graphs Available			
σ(n,p)	0.2-1.7Mev		50Ad, 46B35
σ(n,α)	1.3-1.7Mev		47GIF
n,p and n,α resonances			48S34

Levels 50HLM



N^{14} Ground State

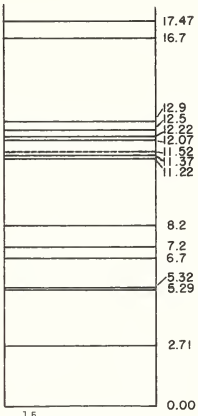
$^{15}_{7}N_{8}$

	0.365%		50N1
	0.363		31U1
	0.380		35W1, 34V1
I	1/2	B	39K11, 40W10
μ	±0.280	M	40Z2(49Po)

σ's

(th n,γ)7.35^{s}N	<0.013mb	45H14

Levels 50HLM



N^{15} Ground State

Also 19 levels reported between 14.8 and 17.5 48HL, 48Lau, 50HLM

$^{16}_{7}N_{9}$

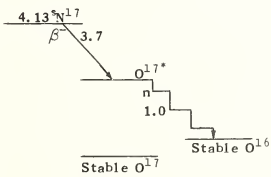
τ	7.35^s		47B3
	7.3		46S5
	7.5		46H17
β^- ~40%	3.8	a$\beta\gamma$	47B3
~40%	4.3	a$\beta\gamma$	47B3
~2%	4.6	cc	47B3
~18%	10.5	a	47B3
	10	cc	46H17
γ	6.2	ac	46B10
	6.2		49M49
	photographic plate		
	6.7	ac	46B10
	7.0		49M49
	photographic plate		

Best estimate of disintegration energy = 10.3 ±0.7 47B3

N-d-p
O-n-p
F-n-α } 50HLM

$^{17}_{9}N_{10}$

τ	4.13^s		48K2
	4.5		49C27



* excited level

Half width of n energy distribution < 0.5 49A4

Neutron energy distribution has high energy tail suggesting 0.6Mev wide level or two distinct levels 49H43

C-α-p
O-n-p
F-γ-2p } 50HLM

β^-	3.7	a	49A4

Most probable neutron energy

0.9	pc	49A4
	from O^{16} recoil	
1.0	cc	49H43
	from knock-on protons	

βn coincidences 49A4

Neutron Cross Sections for Natural Element

σ_s coh	4.2		49S12
σ_s bound	4.15		49S12
	E_n = 0.025ev		
σ_a	<0.9mb	See D_2O	
σ_s	4.2		37G1
σ_t	4.2	See graph	
	E_n = 15-1000ev		
σ_t	3.73		49M40
	Resonances		
E_o	0.440Mev		49A8, 50Ad
	1.0		
	1.3		
	4.0		
	Graphs Available		
σ_t	0.003-2000ev		50Ad,49M40
	0.02-6Mev		47GIF
	0.1-1.4Mev		50Ad
	1.5-300Mev		50Ad
	0.01-0.6Mev		49A8
References on graphs and in 48WH			

14 (8 6)

τ	76.5^S		49S25
β^+ simple	1.8	a	49S25
γ	2.3	a	49S25
N-p-n	chem		49S25

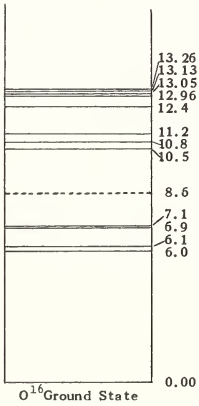
15 (8 7)

τ	1.97^m		49P12
	2.1		35M1,39B5, 48P3,49S25
	2.2		48W13
β^+	1.683	s	49P12
	1.68	a	49S25
	1.7	cc	36F1
Levels ?	4.0		50HLM
	7.9		
C-α-n			50HLM
N-d-n			
N-p-γ			
O-γ-n			
O-n-2n			
F-n-p4n			
O-γ-n	relσ		48P3,48W13

16 (8 8)

	99.759%	atmospheric	50N1
	99.757		44T1
	99.7		49H3
I	0	B	29M1
	σ's		
(~1Mev n,p)	0.014mb		46G31

Levels 50HLM

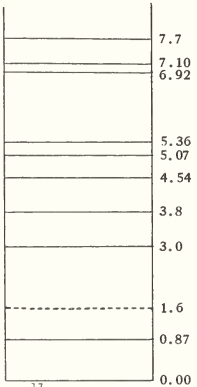


$^{17}_{8}$ 9

0.0374%	atmospheric	50N1
0.039		44T1
0.035		49H3

I 1/2 ? Mic 49L21

Levels 50HLM



O^{17} Ground State

σ's

(th n,α)	0.48	46H27
	<0.4	46E9

$^{18}_{8}$ 10

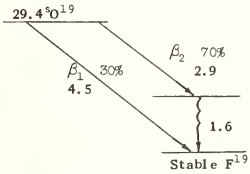
0.2039%	atmospheric	
		50N1
0.204		44T1
0.195		49H3

σ's

(th n,γ) 29.4^{s}O	0.22mb	46S24
	0.20mb	45H14

$^{19}_{8}$ 11

τ	29.4^{s}		44F6
	29.5		46H17
	27.0		47B4



β_1^- 30%	4.5	a	47B4
	4.1	a	44F6
β_2^- 70%	2.9	a	47B4
γ	1.6	a	44F6

O-n-γ
F-n-p } 50HLM

Neutron Cross Sections for Natural Element

σ_s coh	~4		49S12
σ_s bound	~3.5		49S12
	E_n = 0.025ev		
σ_a	≤0.01		46M20
σ_t	4.0		48R6
	E_n = 0.25-40ev		
σ_t	3.3		48R6
	E_n = 1Mev		
σ_t	3.7		See graphs

Graphs Available

σ_t 0.02-40ev		50Ad,48R6,47GIF
See also		49H16
0.02-3Mev		50Ad,47GIF

References on graphs and in 48WH

17
9 8

τ	72.0^s		48P3
	74		38D1
	66		49B27
β^+	2.1	cc	36K2
No γ			48K13
Level ?	3.9		50HLM

N-α-n
O-d-n
O-p-γ
F-γ-2n
F-n-3n
} 50HLM

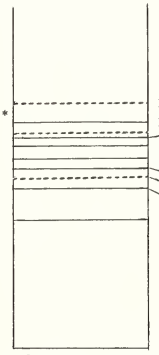
18
9 9

τ	1.87^h		37S1,48P3,49B26
	1.92		44H8
	1.78		38D1
β^+ simple	0.64	s	49B26
	0.7	a	50K14
	0.72	a	41K1
80%	0.6	cc	48H19
20%	0.95	cc	48H19
No γ			48K13
γ	1.4	cc	48H19
K ?			48H19

O-α-pn
O-p-n
O-d-n
O-t-n
F-n-2n
F-d-t
F-γ-n
Ne-d-α
Na-γ-αn ?
} 50HLM

F-γ-n relσ 48P3,48W13

Levels 50HLM



F^{18} Ground State

* 7 levels reported between 10.3 and 11.2 50HLM

19
9 10

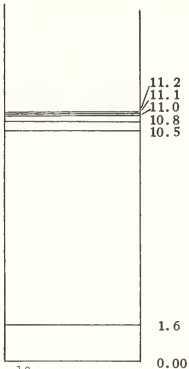
100% 42A2

I	1/2	B	29G1
		S	33C4
μ	2.6283		49P0
		I	49Z2, 49P8, 49S37
		M	41M8

σ's

(th n,γ) 12^sF	0.009	47S33
	0.01	41M6
(~1Mev n,p) 29^sO	0.5mb	46G31
(~1Mev n,α) 7.3^sN	4.5mb	46G31

Levels 50HLM



F^{19} Ground State

20
9 11

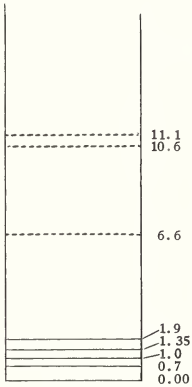
τ 12^s 35C1

β^-	5.1	a	40C11(46B27)
	5.1	cc	39B10
γ	2.2	cc	39B10

5.1Mev β in coincidence with γ, $\gamma\gamma$ coincidences also observed 40C11

F-d-p
F-n-γ
Na-n-α
} 50HLM

Levels 50HLM



F^{20} Ground State

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_t	2.8	41C5
σ_s	2.3	50H5

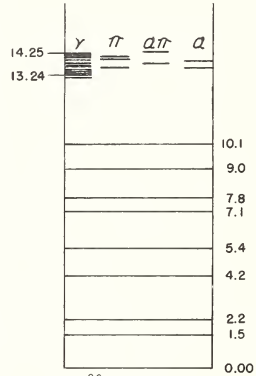
19
10 9

τ	18.2^S		49S25
	20.3		39W2
β^+	2.3	a	39W2, 49S25
	2.2	cc	39W2
No γ			39W2
F-p-n			49S25, 39W2

20
10 10

	89.99%	49H3
	90.51	47D9

Levels 50HLM

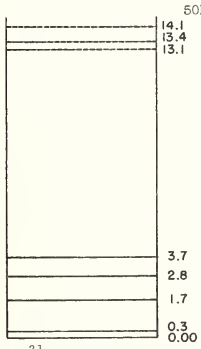


Ne^{20} Ground State

21
10 11

	0.30%		49H3
	0.28		47D9
I	⩾3/2	S	49K21
μ	negative	S	49K21

Levels 50HLM

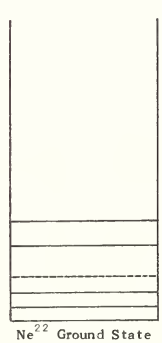


Ne^{21} Ground State

22
10 12

9.72%		49H3
9.21		47D9

Levels 50HLM

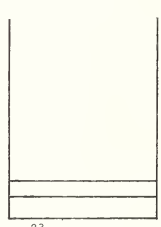


Ne^{22} Ground State

23
10 13

τ	40.7^S		44H4
	40		35A1, 49B27
	43		40P4
β^-	4.3	a	40P4 (46B27)

Levels 50HLM



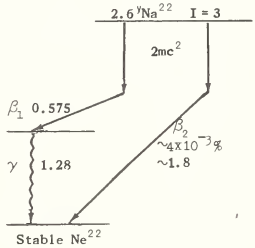
Ne^{23} Ground State

Ne-d-p
Na-n-p
Mg-n-α
} 50HLM

Neutron Cross Sections for Natural Element				21 / 11 10		
σ_s coh	1.5		49S12	τ	$\sim 20^s$	48B22
					23	40C3
σ_s bound	3.5		49S12			
	E_n = 0.025ev					
σ_a	0.46		49P3			
	0.51		49H2			
	0.41		48W19			
σ_s	4.0		37G1			
	Resonances					
E_o						
~1700ev			47L18			
>1000			48H45			
	Graphs Available					
σ_t	0.02-14Mev		47GIF	Ne-p-n		40C3
	0.02-1Mev		49A8,50Ad	Ne-d-n		40P4
	many resonances			Mg^{24}-p-α		48B22
				Ne^{20}-p-γ	f	47B18
Other references on graphs and in			48WH			

22 / 11 11

			τ	2.6^y	49L12	
				2.8	41S13	
				3.0	37L2	
I	3	M	49D1	β_1^+	0.575 s	46G1
μ	1.7454	M	49D1(49Po)		0.55 s	3901
					0.53 a	37L2(46B27)
				β_2^+ ~4x10^{-3}%	~1.8 cc	49M34
				γ	1.277 s	49A7
					1.30 s	46G1
Levels	?		F-α-n		1.3 s	3901



$\beta\gamma$ coincidences		46G1,44M3,49A7
No K capture		44B8,46G1
F-α-n	chem	35F4
	Q = -2.3, -2.64	34B2
Ne^{21}-p-γ	f	47B18
Na-n-2n		47S24
Mg-d-α	chem	37L2
	f,σ	44B8,46C5
	yield	46C9

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23
11 12

100% 36S3

I 3/2 B 33J4
S 33G3
M 40M8
Z 34R1
P 34L4,34E2,47R7

μ 2.2166 49Po
I 49B7,49Z2
M 41M8

σ's
(th n,γ) 14.9^{h}Na 0.6 47S33
see also natural element
(~1Mev n,γ) 14.9^{h}Na 0.29mb 49H5
Other fast n values 48WH
(~1Mev n,p) 41^{s}Ne 0.7mb 46G31
(~1Mev n,α) 12^{s}F 0.4mb 46G31
(~1Mev n,2n) 2.6^{y}Na 0.006mb 47H27

Levels 49AH
3 levels between 10.8Mev and
(10.8+4.3) Mev from resonances in
F-α-n 34B2
F-α-p 34C5,32C1

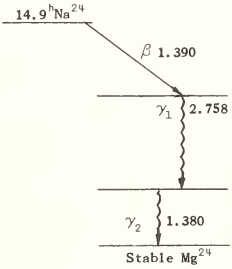
Ne-α-p Q = -2.54 37P4 (37LB)

24
11 13

τ 14.90^h 49W19
14.8 36V1

Levels in Na^{24} 49AH
0.38 Na-d-p
1.26 Na-d-p
3.38 Na-d-p
9 levels between 6.95Mev and
(6.95+0.88) Mev from resonances in
Na-n-γ 47L18,49A8

Na-d-p chem 35L1
Q = 4.76,4.38,3.50,1.38 39M9
Na-n-γ chem 35A1
σ 47S33
Al-n-α chem 35A1
σ 46G31
Al-d-pα f 48H56,47C14
σ 49H47



Mg-γ-p relσ 47H4
threshold = 11.5 49M17
Mg-n-p chem 35A1
relσ 44R1
Mg-d-α f,σ 44B8,46C5
yield 46C9

β^- 1.390 s 46S9
1.4 s 39L6

γ_1 2.758 s 46S9
2.765 s 49R4
2.76 s 49R13,43E1

γ_2 1.380 s 46S9,49R4
1.38 s 43E1

γ's in cascade 46C4,47W2,47B23

No $\beta\gamma$ angular correlation 49G21

$\gamma\gamma$ angular correlation consistent
with I = 4,2,0 48B18

25 11 14					
τ		62.5[S]		46B7	
		62.0		48P3	
		60		44R1	
		58		47B4	
β^-	~45%	2.7	a	47B4	
	~55%	3.7	a	47B4	
		3.3	a	44R1	
		2.8	a	46B7	
γ		>0.5	a	47B4	
Mg-γ-p		relσ		47H4,49B51	
threshold = 14				49M17	
Mg-n-p		chem		47B4	
Al-γ-2p		relσ		48P3	

Neutron Cross Sections for Natural Element			
σ_s coh	2.4		49S12
σ_s bound	4.2		49S12
	E_n = 0.025ev		
σ_a	0.06		49P3
	0.07		49H2
σ_s	3		(48WH)
σ_t	3	See graphs	
	E_n = 1Mev		
σ_t	~3	See graphs	
	Graphs Avsilable		
σ_t	0.02-400ev		48R6,47GIF,50Ad
	0.023-14Mev		47GIF
	0.5-2Mev		49W21
	2-90Mev		50Ad
Other references on graphs and in			48WH

23			
12	11		
τ	11.9^s		43H2
	11.6		39W2
β^+	2.82	cc	39W2
No γ			39W2
Na-p-n			39W2,44D9
threshold ~4.7			39W2
Mg-γ-n			43H2,46B7
threshold = 16.2			49M17
relσ			48W13

24			
12	12		
	78.98%		49H32
	78.60		48W9
Levels			49AH
	1.38	Mg-p-p,Mg-n-n,Na^{24}	
	4.14	Mg-p-p,Na^{24}	
	5.51	Mg-p-p	
Mg-p-p			49R12,43D3,41W12,48F13
Mg-n-n			46L8
25 levels between 11.72Mev and (11.72 +1.85) Mev from resonances in Na-p-γ			41B3,47T19,39C8,36G2
Al-p-α	Q = 1.32		48E7

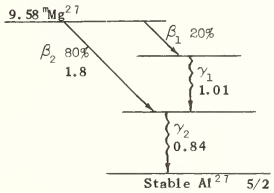
25			
12	13		
	10.05%		49H32
	10.11		48W9
I	5/2	S	49C18
μ	-0.96	S	49C18
Levels			49AH
	0.6	Mg-d-p	
	0.8	Al-d-α	
	1.0	Mg-d-p,Na^{25}	
	1.58	Al-d-α	
	2.54	Al-d-α	
Mg-d-p			
	Q = 5.08,4.52,4.10		50P2
	Q = 5.03,4.45,4.05		49A14
Al-d-α			
	Q = 6.52,5.71,4.94,3.98		49P21

26			
12	14		
	10.97%		49H32
	11.29		48W9
Levels			49AH
	0.44	Na-α-p	
	1.91	Na-α-p,Mg-d-p	
	2.85	Na-α-p,Mg-d-p	
	4.0	Na-α-p	
	5.0	Na-α-p	
	σ's		
(th n,γ)9.58^{m}Mg		0.05	47S33
(~1Mev n,γ)9.58^{m}Mg		0.6mb	49H5
Na-α-p			
	Q = 1.72,1.28,-0.19,-1.13		49M54
	Q = 1.91,-0.2		34K3(37LB)
	Q = -0.4,-2.1,-3.1		36M2(37LB)
Mg-d-p			41P5

$^{27}_{12}15$

τ	9.58^m	43E7
	10.0	39C3
	10.2	35H2

Decay scheme 48B3



β_1^- 20%	~0.9	s	48B3
β_2^- 80%	1.80	s	48B3
	1.74	a	40M9
	1.77	cc	43E7
γ_1	1.01	s	48B3
	1.02	s	41I1
	1.05	cc	43E7
γ_2	0.84	s	48B3, 41I1
γ_3	0.64	s	41I1
$\gamma_3/\gamma_2 < 5\%$			48B3
$\gamma\gamma$ coincidences			48B3
$\beta\gamma$ coincidences			47B4

Mg-d-p	f	35H2
	Q = 4.21	49A14
Mg-n-γ	σ	47S33
Al-n-p	chem	35A1
threshold	~2.5	50G2
	σ	46G31, 50G2

Neutron Cross Sections for Natural Element

σ_s coh	1.5	49S12
σ_s bound	1.5	49S12
	E_n = 0.025ev	
σ_a	0.22	49P3
	0.23	49H2
σ_s	1.35	(48WH)
σ_t	1.6	See graphs
	Resonances	
E_o	2300 ev	49H18
	>10000	49H18
	9100	47L18
	60	48C24
	E_n = 1Mev	
σ_t	~2.5	See graphs

Graphs Available

σ_t	0.025-1000ev	47GIF, 50Ad
	0.01-1.0Mev	47S35, 50Ad
	0.001-10Mev	47GIF
	0.5-4Mev	47A7

Other references on graphs and in 48WH

25 (13 12)

τ	7.3^S	48B22
Mg^{25}-p-n		48B22

26 (13 13)

τ	6.3^S		48B22
	7.2		48W13
	7.0		48P3, 48A8, 39W2, 34F1
β^+	2.8	a	48A8
	2.6	a	38B6(46B27)
	3.4	a	34F1(46B27)

Levels 49AH
10 levels between 5.18Mev and (5.18 + 0.8) Mev from resonances in Mg-p-γ 39C8, 47T19

Mg^{26}-p-n		48B22
Al-γ-n		46B7
threshold = 14.4		47B25
14.0		49M17
relσ		48P3, 48W13
Na-α-n		37M1, 34F1
Mg-p-γ		47T19, 39C8

27 (13 14)

100% 42A2

I	5/2	S	38H6
		M	49L15
μ	3.639		49Po
		I	49Z2, 49B7
		M	39M8
q	0.156	M	49L15

σ's

(th n,γ) 2.3^mAl	0.21	47S33
(~1Mev n,γ) 2.3^mAl	0.4mb	49H5
(~1Mev n,p) 9.6^mMg	2.8mb	46G31
(14Mev n,p) 9.6^mMg	~30 mb	50G2
(~1Mev n,α) 14.9^hNa	0.6mb	46G31

See also natural element
Other fast n,γ; n,p; n,α values 49B4, 48WH

Levels 49AH

	0.84	Al-p-p, Mg^{27}
	1.07	Al-p-p, Mg-α-p, Mg^{27}?
	1.48 ?	Mg^{27}
	1.79	Al-p-p, Mg^{27}
	2.28	Al-p-p
	2.82	Al-p-p
	3.07	Al-p-p

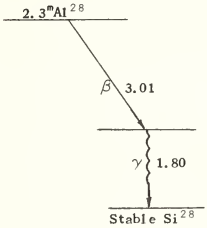
Al-p-p		48H59, 49B30, 48F13, 43D3, 49R12

10 levels between 8.28Mev and (8.28 + 0.96) Mev from resonances in Mg-p-γ 47T19, 39C8

Mg-α-p	Q = -1.82, -2.87	34D1(37LB)

28
13 15

τ	2.30^m		49S40, 43E7, 35A1
	2.4		36E1
	2.6		35M2, 36C1, 37R1



β^-	3.01	s	48B3
	2.75	a$\beta\gamma$	47B4
	3.10	a	47D2
γ	1.80	s	48B3, 41I1
	1.80	ac	47B4
Al-n-γ	σ		47S33
Si-n-p			35A1, 47B4
Si-γ-p			46B7
	relσ		47H4, 48P3
Mg-α-p	f, relσ		48S35
Q = -1.05			34D1
P-n-α	chem		35A1
threshold ~3			45T7

Levels in Al^{28} 49AH, 49P21

1.03
1.48
1.57
2.16
2.61
2.97
3.41
3.90
4.47
4.72
4.88
5.16
5.44
5.76

} Al-d-p

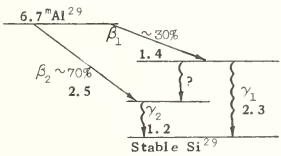
13 levels between 7.63Mev and (7.63 + 2.8) Mev from resonances in Al-n-γ 47A7, 47S35, 47L18

Al-d-p
Q = 5.45, 4.42, 3.68, 3.29, 2.84, 2.48, 2.04, 1.55, 0.98, 0.73, 0.57, 0.29, 0.01, -0.31 49P21
Q = 5.46, 4.46, 3.98, 3.31 49A14
Q = 5.79, 5.11, 3.10, 2.12, 0.64 35M2

29
13 16

τ	6.56^m		49S40
	6.7		39B9
	6.8		48P3

Decay scheme proposed by 49S40



β_1^- ~30%	1.4	a$\beta\gamma$	49S40
β_2^- ~70%	2.5	a$\beta\gamma$	49S40
γ_1	2.3	ac	49S40
γ_2	1.2	ac	49S40
$\beta\gamma$ coincidences			49S40

See also Si^{29}

Si-γ-p		46B7
	relσ	48P3, 47H4
Si-n-p	σ	46G31
P-γ-2p		46B7
	relσ	48P3, 47H4
Mg-α-p		39B9, 49S40

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	0.10	49P3
	0.17	49H2
σ_s	1.7	37G1
σ_t	2.2	48R6

Fast n values 49W21, 48WH

Graphs Available

σ_t	0.01-100ev	48R6, 47GIF, 50Ad
	0.5-2Mev	49W21
	many resonances	49W21

27 (14 13)

τ	4.9^s		40C3, 41E3
	4.5		48W13
β^+	3.5	cc	40B1
	3.7	cc	40M1

Mg-α-n 41E3

Al-p-n 40B1

threshold = 6.1 39K2

Si-γ-n rel σ 48W13

threshold = 16.8 49M17

16.9 47B25

28 (14 14)

92.19%	49H3
92.16	48W9
92.28	46I1

Levels 49AH

1.8	Al-d-n, Al^{28}
4.47	Al-d-n, Si-p-p
4.91, 6.11, 6.65, 7.10, 7.55, 8.18, 9.16	Al-d-n

Si-p-p 48F13

53 levels between 11.69Mev and (11.69 + 2.451) Mev from resonances in Al-p-γ 47B27, 47T19, 40P6

3 levels between 10.40Mev and (10.40 + 5.3) Mev from resonances in Mg-α-p 36E2, 35F1, 34D1

σ's

(~1Mev n,p) 2.3^mAl 3.0mb 46G31

Al-d-n

Q = 9.08, 7.30, 4.61, 4.17, 2.97 2.43, 1.98, 1.53, 0.90, -0.08 49P13

29 (14 15)

	4.70%	49H3
	4.71	48W9
	4.67	46I1

Levels 49AH

1.29, 2.06, 2.43, 3.08, 3.60, 4.09, 4.87	Si-d-p

See also Al^{29}

σ's

(~1Mev n,p) 6.7^mAl 2.7mb 46G31

Si-d-p

Q = 6.21, 4.92, 4.15, 3.78, 3.13, 2.61, 2.12, 1.34 49M54

Q = 6.16, 4.87, 3.75 49A14

S-n-α

Q = 1.16 48S34

30 (14 16)

	3.12%	49H3
	3.13	48W9
	3.05	46I1

Levels 49AH, 49B30

2.3, 3.6, 4.8, ~5.5	Si-d-p, Al-α-p
7.18, 8.20, 9.26, 9.87, 10.86	Al-α-p

σ's

(th n,γ) 2.7^hSi	0.12	47S33
(~1Mev n,γ) 2.7^hSi	1.1mb	46H34

Al-α-p

Q = -1.27, -3.22, -4.96, -5.98 -7.04, -7.65, -8.64 49B30

Q = 2.22, -0.06, -1.44, -2.63 48B25

Q = 2.26, -0.02, -1.32, -2.49 34D1

Q = 2.3, 0.0, -1.1, -2.6 34H1

Q = 2.25, 0.01, -1.15 40M8

Si-d-p

Q = 8.38, 5.98, 4.59, 3.56, 2.72 49M54

31 (14 17)

τ	2.62^h		38C2
	2.7		49P15
	2.8		40A2, 37N1
β^-	1.5	a	37N1
	1.8	cc	36K2

No γ 37N1

Levels 49AH

0.59	Si-d-p, P-n-p
1.29, 1.79, 2.29, 2.89	Si-d-p

Si-d-p chem 37N1

Q = 4.95, 4.36, 3.66, 3.16, 2.66, 2.06 49M54

Q = 4.16 49A14

P-n-p σ 48M37, 45T7

threshold = 1.40 45T7

Q = -0.97, ~-1.7 48M37

Si-n-γ σ 47S33

S-n-α 36S1, 38C2

Neutron Cross Sections for Natural Element		
	E_n = 0.025ev	
σ_a	**0.15**	49P3
σ_s	**10.4**	37G1
σ_t	**4.3**	See graphs
	13.6	37G1
	E_n = 1Mev	
σ_t	~3	See graphs
Other fast n values		48WH
	Graphs Available	
σ_t	**0.02-300ev**	47GIF,50Ad
	0.03-3Mev	47GIF,50Ad
σ(n,p)	**1.4-5Mev**	45T7,47GIF

29
15 14

τ	**4.6**^{s}		41W2
β^+	**3.6**	cc	41W2
Si-p-n			41W2
P-γ-2n			46B7
	relσ		48P3
Si-d-n	Q = -0.80		48P15

30
15 15

τ	**2.18**^{m}		38C2
	2.55		37R1
	2.5		48P3
β^+	**3.5**	s	41M4
	3.4	a	34F1(46B27)
	3.0	cc	40B1
Levels			49AH
	1.02		Al-α-n,Si-d-n
	5.64+0.315		Si-p-γ
	5.64+0.400		Si-p-γ
Si-p-γ			47T19
	E_γ(mean) = 5.2		47T19
Al-α-n	yield,σ		49H46
	chem		41M4
	Q = -2.93,-3.91		48P15
Si-p-n			40B1
Si-d-n	Q = +3.38,+2.11		48P15
P-n-2n			37P2
	threshold = 5-7		38S14
P-γ-n	relσ		48P3
	threshold = 12.3		49M17
	Not produced by		
P-d-t	σ(7.5Mev d,t)<5x10^{-6}		49K36

31
15 16

		100%	42A2
I	1/2	B	33A1
		S	49C31
μ	1.1309		49Po
		I	49C2,49B7, 48P9
		S	49C31
	σ's		
	(th n,γ) 14.3^d P	0.2	47S33
	(th n,γ)	0.15	49P3
	(~3Mev n,p) 2.6^h Si	0.074	48M37
	Graphs Available		
σ(n,p)	**1.4-5Mev**		45T7,47GIF

Levels		49AH
0.44		Si-d-n
1.02		Si-α-p,Si-d-n
1.74		Si-α-p,Si-d-n
8.02+0.355		Si-p-γ
8.02+0.483		Si-p-γ
Si-p-γ		47T19
7 levels between 10.26Mev and (10.26+6.8) Mev from resonances in		
Al-α-n		36W1,35F5,37S8
Al-α-p		32C1,34D1
Si-d-p	Q = 4.56,4.12,3.57, 2.78	48P15
Si-α-p	Q = -2.23,-3.28,-3.92	34H1(37LB)

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32
15 17

τ			14.30^{d}	38C1
			14.35	48K28
			14.07	40M7
β^-	1.712	s		46S9
	1.715	s		47P17
	1.69	s		49L6
	1.72	s		39L6
	1.75	s		41W7
No γ				36K2
P-n-γ	σ			47S33
P-d-p	chem			37N1
	yield			47C9
	Q = +5.9			40P5
S-n-p	chem			35A1
	f			48K28,47B26
	Q = -0.93			41H10
Cl-n-α				35A1
	Q = +0.44, σ			47M31
Si-α-p				39K1

Average disintegration energy found to be 0.685 calorimetrically 47C16

$<5\times10^{-5}$ e^+ per disintegration due to pair formation 47S29

Complex e^- from Pb radiator attributed to ejection of L and M e^- by K X-rays. Found with both P^{32} and Bi^{210} (RaE) 47S29

33
15 18

34
15 19

τ			12.4^{s}	46B1
			12.7	40C12
β^-	25%	3.2	a	46B1
	75%	5.1	a	46B1
S-n-p		chem		46B1,40C12
Cl-n-α		chem		46B1,45H2

Neutron Cross Sections for Natural Element

σ_s coh	1.2		49S12
σ_s bound	1		49S12
$E_n = 0.025$ev			
σ_a	0.47		49P3
	0.52		49H2
σ_s	1.1		37G1
σ_t	1.6	See graphs	
Values at other energies			49H16

Resonances

E_o	σ_o	Γ	
108kev	21.5	18	49A13
205			49A13

Many resonances between 0.5 and 2Mev 49W21

Graphs Available

σ_t 0.025-10ev		50Ad, 48R6, 47GIF
0.016-0.250Mev		49A13
0.5-2Mev		49W21

Other references on graphs and in 48WH

31
16 15

τ	3.18^s		41E3
	3.2		41W2
	2.9		41H15, 48W13
β^+	3.87	cc	41E3
	3.85	cc	41W2
P-p-n			41W2
Si-α-n			41E3
S-γ-n			41H15
	relσ		48W13
threshold =	14.8		49M17
	15.0		47B25

32
16 16

	95.06%		38N2
I	0	B	3601

Levels 49AH

2.25	S-p-p
4.34	S-p-p

S-p-p 43D3

5 levels between 10.0Mev and (10.0 + 0.92) Mev from resonances in P-p-γ 47T19, 39C8

σ's

(2.9Mev n,α)	2.9	41H10
(~1Mev n,p) 14.3^{d}P	~0.012	46G31
Other fast n values		48WH

Graphs Available

σ(n,p) 2-3.7Mev		47B26, 50Ad
1.6-5.8Mev		48K28

33
16 17

	0.74%		38N2
I	3/2	Mic	48T13
μ	0.6-0.9	Mic	49J9
q	-0.08	Mic	49T17

Levels 49AH

0.79	4.15
1.90	4.42
2.17	4.70
2.85	5.11
3.15	5.63
3.88	6.30

all from S-d-p
2 levels from S-n-α 48S34

S-d-p 49D28, 41S15
Q = 6.48, 5.69, 4.58, 4.31, 3.63, 3.33, 2.60, 2.33, 2.06, 1.78, 1.37, 0.85, 0.18 49D28
Q = 6.62, 5.57, 4.45, 3.40, 2.29, 1.30 41S15

Cl-d-α	Q = 9.1	41S14
S-n-γ	E_γ(max) = 7.6	49K15

34
16 18

	4.18%		38N2
I	0	?	47T18

Levels 49AH

0.82	S-d-p
1.9	p^{34}
3.4	Cl^{34}
?	P-α-p

σ's

(th n,γ) 87^{d}S	0.26	47S33

S-d-p	Q = 8.67, 7.85	49D28
P-α-p	Q = 0.31, -1.0, -2.5, -4.5	36M2(37LB), 36P1(37LB)

35
16 19

τ	87.1^d		43H6
	88		40L8, 41K3
I	3/2	Mic	49C12
q	+0.06	Mic	49C12(49T17)
β^-	0.166	s	48A3
	0.167	s	49P20
	0.169	s	48B1
	0.167	a	47S28

Fermi plot straight above 16kev 48A3

Discussions of spectral shape 48C10, 48B1, 48A3, 49C32

Cl^{35}-n-p	chem	42K9
Cl-n-p	chem, yield	41K3
	σ	49M27, 47S33
	Q = + 0.52	44G4
Cl-d-α	chem, yield	41K3
S-n-γ	σ	47S33
S-d-p	chem	39C7

36 16 20				37 16 21				
	0.0136%		49L21	τ	5.04^m		46B1	
	0.016		68N2		5.0		46H25	
I	0	Mic	49L21	β_1^- 10%	4.3	a	46B1	
					4.0		46H25	
				β_2^- 90%	1.6	a	46B1	
					1.4		46H25	
				γ	2.6	a	46B1	
					2.75	ac	46H25	
				$\beta\gamma$ coincidences			46B1	
	σ's							
(th n,γ)5.0^mS		0.14	46H35					
				Cl-n-p	chem		46B1	
				S-n-γ			46H25	
				A-n-α	Q = -1.8 ?,σ		46G32	

Neutron Cross Sections for Natural Element		
σ_s coh	12.2	49S12
σ_s bound	15	49S12
	$E_n = 0.025$ev	
σ_a	32.7	49P3
	32.1	49H2
σ_t	55	See graph
	Resonance	
E_o	1800 ev	47L18
Assigned to Cl^{37}		47L18
	$E_n \sim 3$Mev	
σ_t	3.4	39Z1
Other fast n values		48WH
	Graphs Available	
σ_t	0.023-70 ev	47GIF
See also		49H16

33 (17 16)			
τ	2.8^s		48S20, 40H7
	2.4		41W2
β^+	4.1	cc	41W2
S-d-n			48S20, 40H7
S-p-n			41W2

34 (17 17)			
τ	33.2^m		48W13
	33.0		48P3
	33		38B6, 36S1
β^+ 20%	2.4	cc	46H1
80%	5.1	cc	46H1
	3.0	a	38B6(46B27)
	3.4	a	34F1(46B27)
γ	3.4	cc	46H1
P-α-n	chem		38B6, 34F1
	yield		37R1
S-d-n	chem		46H1, 36S1
Cl-γ-n	relσ		48P3, 48W13
Cl-n-2n	chem		37P2
S-α	chem		40S7
S-t-n			50K14

35 (17 18)			
	75.4%		36N4
I	3/2	Mic	47T16
μ	0.8210		49Po
		I	49C2, 49B7
		M	40S12
q	-0.0795	M	49D14
		Mic	49T17, 48G22
Levels			49AH
0.6			S-α-p
1.5			S-α-p
σ's			
(th n,p) 87.1^dS	0.34		49M27
	0.17		47S33
(th n,p)	0.34		44G4
(th n,γ)	$\sim$32	See element	
($\sim$3Mev n,α) 14.3^dP	17mb		47M31
Other fast n values			48WH
S-α-p	Q = -2.1, -2.7, -3.6		
			35H7(37LB)
			36B7(37LB)

36 (17 18)			
τ	$4.4\times10^5{}^y$	From specific disintegration rate	49W15
	3.6×10^5	From specific disintegration rate	49R11
	2.0×10^5	From n,γ yield	49R11
	10^6	From n,γ yield	4703
I	2	Mic	49T10
q	-0.0172	Mic	49T10
Levels			49AH
0.96			Cl^{35}-d-p
4.81			Cl^{35}-d-p
Cl^{35}-d-p	Q = 6.31, 5.35, 1.50		41S14
	chem		41G2

36 (17 18)			
β^-	0.713	s	49W16
	0.73	a	49R11, 49W15
	0.66	a	4703
	0.64	a	41G2
γ weak	0.10	a	49J8
	0.57	a	49J8
bremsstrahlung or annihilation?			49J8
No γ unless of energy < 20kev or of low intensity			49W15
$\beta^+/\beta^- < 10^{-4}$			49W15
$0.57\gamma/\beta^- < 3\times10^{-4}$			49J8
β spectrum has forbidden shape consistent with $\Delta I = 3$, no			49W16
Cl-n-γ	chem		41G2
	σ		47S33, 49M27
E_γ(max) = 9.8			49K15

37
17 20

	24.6%		36N4
I	3/2	Mic	47T16
μ	0.683		49P0
		M	39K7
q	-0.0621	M	49D14
		Mic	49T17, 48G22
Level	2.6		S^{37}
	σ's		
(th n, γ) $38.5^{m}Cl$		0.6	47S33
		0.4	4104
(~1Mev n, γ) $38.5^{m}Cl$		0.8mb	49H5

38
17 21

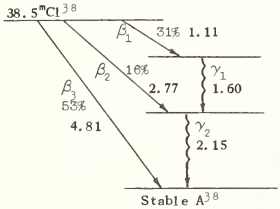
See below

39
17 22

τ	55.5^{m}		49H30
	1^{h}		48M3, 48H27
β^-	2.5	a	49H30
A-γ-p	chem		49H30

38
17 21

τ	38.5^{m}	46H2
	37.5	37H1, 40C4
	37.0	45S2, 36V1



β_1^-	31%	1.11	s	50L2
	36%	1.19	s	46H2
		1.1	s	39W5
β_2^-	16%	2.77	s	50L2
	11%	2.70	s	46H2
		2.6	a$\beta\gamma$	41W3
β_3^-	53%	4.81	s	50L2
		forbidden shape		50L2
	53%	~5.2	s	46H2
		5.0	s	39W5
		4.99	a$\beta\gamma$	41W3
γ_1	43%*	1.60	s	46H2, 40C4
		1.6	s	41I1
γ_2	57%*	2.15	s	46H2
	57%*	2.5	s	40C4
γ		1.19	s	41I1

* % of γ's

Levels		49AH
1.00		Cl^{37}-d-p
1.92		Cl^{37}-d-p
6.21 + 0.0018		Cl-n-γ
Cl^{37}-n-γ	chem	40K3
Cl^{37}-d-p	Q = 4.02, 3.02, 2.10	41S14
Cl-d-p	chem	46H2
	yield	46C9
Cl-n-γ		47L18
	σ	47S33, 4104
K-n-α	chem	37H1

Cross-over γ, if any, in $< 3 \times 10^{-4}$ disintegrations	49M8
$\beta\gamma$ and $\gamma\gamma$ coincidences	41I1
Summary of early work	46H2

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	0.6	43W8
σ_s	0.75	50H5
σ_t	1.4	See graph
	Resonances	
E_o	> 1000 ev	50H5, 49M40
	Graphs Available	
σ_t	0.01-200 ev	48M34, 50Ad
	15-10,000 ev	49M40, 50Ad

35 (18 17)

τ	1.84^S		48S20
	1.88		41E3
	2.2		41W2
β^+	4.4	cc	41E1, 41W2
S-α-n		chem	41E3, 48S20
Cl-p-n			41W2

36 (18 18)

0.337%	50N1
0.35	47D9

37 (18 19)

τ	34.1^d	44W2
K capture		44W2
L capture		49P22
L capture /K capture ~0.08		49P22
No γ		44W2
Cl K_α X-ray		44W2
Cl-p-n	chem, yield	44W2
Cl-d-2n	chem, yield	44W2
K-d-α	chem, yield	44W2
S-α-n	chem, yield	44W2
Ca-n-α	chem, yield	44W2
Not produced by		
K-n		44W2
Cl-α		44W2

Levels 49D29

1.53	A^{36}-d-p
1.67	
2.27	
2.56	
3.46	
5.01	

A^{36}-d-p
Q = 6.59, 5.06, 4.92, 4.32, 4.03, 3.13, 1.58 49D29
Possibly others 49D29

Cl-p-n
Q = -1.596 48R10

38 (18 20)

0.063%	50N1
0.08	47D9

Levels 49AH

2.15	Cl-α-p, Cl^{38}, K^{38}
3.75	Cl-α-p, Cl^{38}

7 levels between 10.44Mev and (10.44 + 0.97)Mev from resonances in Cl-p-γ 47T19, 39C8

Cl-α-p Q = 0.1, -2.5, -4.2 36P1

* "chem" on the Argon pages indicates separation which was carried out by physical means.

39
18 21

τ long 49H30

4^m activity sometimes assigned here not found from
A-γ-n 49H30
K-n-p 37H1

d 55^mCl ? 49H30

40
18 22

99.600% 50N1
99.57 47D9

Relative abundance of A^{40} higher in potassium minerals than in the atmosphere due to decay of K^{40} 48A5

Levels 49AH
1.5 K^{40}, A-p-p
2.4 A-p-p

A-p-p 47H30

σ's

(th n,γ)	0.6	43W3
(pile n,γ) 1.78^hA	1.2	43K6
(~1Mev n,γ) 1.78^hA	0.93mb	49H28

41
18 23

τ 1.78^h 49B57
1.82 46B11,36S2

β^- simple	1.25	s	49B57
	1.18	a	46B11
	1.1	a	36S2
0.7%	2.55	a	46B11

Levels 49D29
0.66
1.21
1.34
1.94
2.27
2.80
3.29
3.69
4.01
} A-d-p

γ	1.3	ac	46B11
	1.3	cc	36S2
	1.4	cc	36R1
	α~0		49B57

γ in coincidence with 1.18β 46B11

A-d-p
Q = 3.84, 3.18, 2.63, 2.50, 1.90, 1.57, 1.04, 0.55, 0.15, -0.17
49D29

A-d-p chem, f 36S2
A-n-γ 36S2
σ 43K6
K-n-p 46B11,37H1

* "chem" on the Argon pages indicates separation which was carried out by physical means.

Neutron Cross Sections for Natural Element		
σ_s coh 1.5 49S12		
σ_s bound ~2 49S12		
$E_n = 0.025$ev		
σ_a 2.05 49P3,49H2		
σ_s 5.6 37G1		
σ_t 8.2 35D4		
Graphs Available		
σ_t 0.015-0.6Mev 49P23,50Ad		
many resonances		
0.02-2.8Mev 47GIF		
Other references on graphs and in 48WH		

?	38 19 19	39 19 20
τ 1.3^s 48L7	τ 7.5^m 47R3 7.6 48P3 7.7 37R1 7.8 37H1	93.08% 50N1 93.25 49H32 K^{39}/K^{41} abundance = 13.6 48W9
	β^+ 2.53 a 47R3 2.3 a 37R1 2.6 a 37H1(46B27)	I 3/2 M 40K9 Z 35M8
		μ 0.3905 49P0 M 49K33
	γ ~2.1 a coin 47R3	
		σ's (th n,γ)K^{40} ~3 49H48
K-γ-2n ? 48L7	Cl-α-n chem 37H1,47R3 chem,yield 37R1 Ca-d-α chem 37H1 K-n-2n 37P2 K-γ-n relσ 48W13,48P3 threshold = 13.2 49M17	

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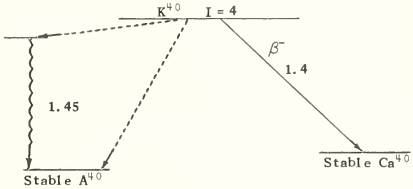
$^{40}_{19}K_{21}$

	0.0119%		50N1
	0.010		49H32
Summary of early work on K abundances			48W9
τ_β	16.1×10^8 y	*	49F19
	15.0×10^8	**	48G8
	13.2×10^8	**	49S42
	12.0×10^8	**	48H58
	$15.4\ 10^8$	**	38B8
	$7.0\ 10^8$	***	47B7
Radioactivity assigned to K^{40}		ms	37S4



I	4	M	49D1
μ	-1.29	M	49D1
Levels in K^{40}			49AH
	0.81		K^{39}-d-p
	2.01		
	2.56		
	3.3		
	3.7		
	4.2		
	4.8		

K^{40} produced by

K^{39}-d-p

Q = 5.48, 4.67, 3.47, 2.92, 2.2, 1.8, 1.3, 0.7 — 50S3

A-p-n — f — 48R11

K-n-γ — chem, σ — 49H48

E_γ(max) = 7.2 — 49K15

β^-	1.40	s	49A15
	1.36	scin	50B8
	1.35	s	46D1
	1.41	a	48H58, 46H7
	1.45	a	49F19
	1.3	a	47H8
	1.7	cc	48F1

β spectrum has third forbidden shape — 50B8

No $\beta\gamma$ coincidences — 47M7

γ	1.45	scin	50B9
	1.47	scin	50P4
	1.54	a coin	46H7, 48H58
	1.55	a	47G7
	1.5	s	49C33
	1.5	a	47M7

γ's/sec(gram of K) = 3.6 — 47G7, 49S31

E_γ /sec(gram of K) = 4.9Mev — 48A4

γ/β^- = 0.05		49F19
	0.087	48H58
	0.127	48G8
β^+/γ < 0.025		50B9
Argon K X-ray		47B7
X-ray		43T1

K capture/β^-	1.9	†	47B7, 48G8
	~3	††	48A4
	~3.5	†	43T1
	<0.1	†††	48S15
	~0.02	†††	48A5

† From measurement of ratio of X-rays to β's

†† From measurement of ratio (radiogenic Ca^{40})/K^{40} = 11 for lepidolite 2.1×10^9 years old. This ratio determines τ (K-capture) if τ_β is known. Assuming $\tau_\beta = 16.0\times10^8$ y
τ (K-capture) = 5.1×10^8
(total) = 3.9×10^8

††† From measurement of Argon content in minerals

* Enriched material used

** Natural K used. τ_β calculated assuming relative abundance of K^{40} = 0.0119%

*** Assumed abundance not stated

41
19 22

	6.91%		50N1
	6.75		49H32
K^{39}/K^{41} abundance = 13.6			48W9
I	3/2	Z	36M3
		M	40K9
μ	0.2148		49Po
		M	40K9
Levels	1.3		A^{41}

5 levels between 7.80Mev and (7.80 + 1.2)Mev from resonances in A^{40}-p-γ 48B26

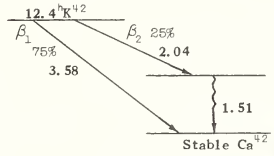
σ's

(th n,γ) 12.4^hK	1.0		47S33
(~1Mev n,γ) 12.4^hK	2.9mb		49H5

42
19 23

τ	12.44^h		47S8
	12.5		37H1

Decay scheme 47S8



Levels in K^{42} 0.62, 1.18, 1.97, 2.29 } K^{41}-d-p

K^{41}-d-p

Q = 5.12, 4.50, 3.94, 3.15, 2.83 50S3

K-d-p	chem, yield		37H1
	yield		46C9
K-n-γ	chem		37H1
	σ		47S33
Sc-n-α	chem		37H1, 47B4
Ca-n-p	chem		37H1

β_1^-	3.58	s	47S8
	3.60	s	47P17
~70%	3.5	a	47B4

Spectral shape consistent with $\Delta I = 2$, yes 47S8 (49S41)

β_2^- 16-25%	1.92	s	47S37
	1.9	s	47P17
~30%	~1.8	a	47B4
	complex		47B4
γ	1.51	s	47S8
	1.50	s	47P17
	inhomogeneous		47B4

Possibly very weak high energy γ 47S8

β_1^- not in coincidence with any γ 47B4

Summary of early work on K^{42} 47S8

No $\gamma\gamma$ coincidences 47S37

43
19 23

τ	22.4^h		4905
β^-	0.24	s	4905
	0.81	s	4905
γ	~0.4	a	4905

No β^+ 4905

A-α-p chem 4905

?

τ	18^m	37W1

Ca-n-p ? chem 37W1

Not produced by

A-α 40W2

Neutron Cross Sections for Natural Element	?	39 20 19
σ_s coh 2.9 49S12	τ 4.5^m 37P2,40W2	τ 1.06^s 43H2
$E_n = 0.025$ev σ_a 0.41 49P3 0.43 49H2		
σ_t 4.4 40R9		
σ_t ($CaCO_3$) 5.5 ce per molecule See graph		
$E_n \sim 2.5$Mev σ_t 3.9 39A5		
Graphs Available σ_t($CaCO_3$) 0.06-10,000 ev 48H46	Ca-fast n 37P2,40W2	Ca-γ-n relσ 48W13 threshold = 15.9 49M17 16 47B25
σ_t 0.02-0.6Mev 49A8,50Ad several resonances		

40 20 20	41 20 21	42 20 22
96.92% 48W9 96.96 38N2	τ ? 8.5^d activity formerly assigned here not found 47M12,4705 Levels 49AH 1.95 2.41 2.96 3.23 3.49 3.67 3.86 Ca-d-p 6 levels between 8.28Mev and (8.28 + 0.5) Mev from resonances in Ca-n-γ 49A8 K-p-n Q = -1.22 48R10 Ca-d-p Q = 6.09, 4.14, 3.88, 3.13, 2.86, 2.80, 2.42, 2.23 49S44, 49S43	0.64% 48W9,38N2 Levels 49AH 1.5 K^{42}, K-α-p 2.6 K-α-p K-α-p Q = -0.89, -2.3, -3.5 36P1(37LB)

43
20 23

	0.13%	48W9
	0.14	38N2
Levels	~0.4	K^{43}
	1.0	Sc^{43}
A-α-n	f	38P7
	Q = -4.0, -5.6 ?	

44
20 24

	2.13%		48W9
	2.06		38N2
Levels	1.33		Sc^{44}
(th n,γ) $152^{d}Ca$	σ's	0.6	47S33

45
20 25

τ	152^{d}		47M12
	180		40W2
β^-	0.254	s	50M3
	0.248	s	47P10
	0.260	a	48S2
	0.32	a	49M32
No harder β			48S2
No γ			49M32, 48S2, 47P10
Sc-n-p			48S2
	chem		40W2
Ca-d-p	chem		40W2
Ca-n-γ			40W2
	σ		47S33
Ti-n-α	chem		48H47

46
20 26

	0.0032%	48W9
	0.0033	38N2

47 ?

τ	5.8^{d}	47M12
β^-	1.1	47M12
γ	1.3	47M12
Production methods not stated		47M12

48
20 28

	0.179%	48W9
	0.19	38N2

$^{49}_{20}$ $_{29}$		
τ 8.5^{m} 49D30 β^- 2.7 a 49D30 γ 2.7 a 49D30 2.5^{h} and 30^{m} activities previously assigned here probably due to impurities 49D30 Ca^{48}-n-γ chem 49D30		

Neutron Cross Sections for Natural Element		
$E_n = 0.025$ev σ_a 12 49P3 31 49H2 See activation σ of Sc^{45}		

41 21 20	42 21 21	43 21 22
τ 0.87^s 41E3		τ 3.92^h 45H3 4.0 40W1
β^+ 4.94 cc 41E3		β^+ 0.4 a 40W1 1.1 s, a 45H3 1.4 a 40W1
		γ 1.05 s 46P1 1.0 a 40W1 1.65 a 45H3
		$\beta^+/\gamma \sim 4$ 45H3
Ca-d-n 41E3		Ca-α-p chem 45H3, 37W2 Ca-d-n chem 45H3 Ca-p-n chem 45H3
		Can be detected in presence of 3.9^{h}Sc^{44} 45H3

$^{44}_{21}Sc_{23}$

τ_1	2.44 d		45H3
	2.2		48W13, 40W1, 42S1
IT			42S1, 40W1
γ	0.269	sc	42S1
	$\alpha = 0.07$, K/L = 8		42S1
	$\alpha = 0.5$		41H1
	0.28	ac	45H3
Sc-n-2n	chem		45H3
Sc-γ-n	relσ		48W13
K-α-n	chem		45H3, 40W1
Ca-d-n	chem		45H3
threshold = 4			42S1
p 3.9 h Sc			42S1, 40W1

τ_2	3.96 h		48W13
	3.92		45H3
	4.1		42S1
K			45H3
β^+	1.45	s	42S1
Fermi plot not straight.			
Spectrum complex?			
	1.43	a	45H3(46B27)
	1.5	a	40W1
γ	1.33	a	45H3
$\beta^+/\gamma \sim 1/3$			45H3
K X-ray			45H3
Sc-n-2n	chem		45H3
Sc-γ-n	relσ		48W13
K-α-n	chem		45H3, 40W1
Ca-d-n	chem		45H3
Ca-p-n	chem		45H3
d 2.4 d Sc			42S1, 40W1

$^{45}_{21}Sc_{24}$

	100%		42A2
I	7/2	S	34S1, 34K1
μ	4.8	S	37K2

σ's

(pile n, γ) 20 s Sc	10	48G16
(th n, γ) 85 d Sc	>13	46B25
	22	47S33

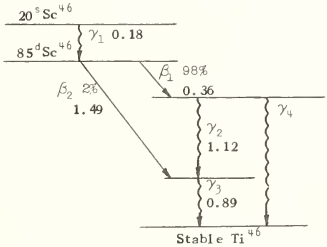
See also natural element

Activation σ falls off faster than 1/v for both 20 s and 85 d Sc 48G16

$^{46}_{21}Sc_{25}$

τ_1	20 s		48G16
τ_2	85 d		49F3, 37W4
β_1^- 98%	0.36	s	48P2
	0.358	s	47F2
	0.36	s	47M9
β_2^- 2%	1.49	s	48P2
	1.5	a	40W1
γ_1	0.18	a	48G16
	$\alpha \sim 1$		48G16
γ_2	1.12	s	48P2
	$\alpha_K = 0.0004$		48P2
	1.116	s	47F2
	1.12	s	47M9
γ_3	0.89	s	48P2
	$\alpha_K = 0.0008$		48P2
	0.883	s	47F2
	0.90	s	47M9
γ_4	$1.63 < E_\gamma < 2.3$ in 1.2×10^{-5}% of disintegrations		49F5
$\gamma\gamma$ coincidences			48M9, 48J7
No K capture			47M9
$\beta\gamma$ coincidences only for 0.36 β^-			48M9, 48J7

Additional level of Sc^{46} at 2.30Mev. See Sc-d-p below.



$\gamma\gamma$ angular correlation consistent with I = 4, 2, 0 43B18

20 s Sc^{46} produced by

Sc-n-γ 48G16

85 d Sc^{46} produced by

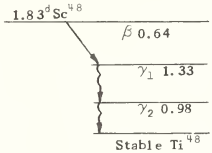
Sc-n-γ	σ	46B25, 47S33
Ti-n-p	σ_{eff}	48H47
Ca-α-p	chem	40W1
Sc-d-p	chem	37W4
Q = 4.48, 6.78		39D7
Ti-d-α		37W3

$^{47}_{21}Sc_{26}$

τ	3.43^d		49K12
	3.4		45H4
β^-	0.61	a	49K12
γ			49K12
Level	1.3		Ca^{47}
Ti^{49}-d-α	chem		49K12
Ca-α-p	chem		45H4
Ti-d-α	chem		44H3
Ti-n-p	σ_{eff}		48H47

$^{48}_{21}Sc_{27}$

τ	1.83^d		49K12, 45H4



β^-	0.64	s	42S1
	0.57	a	49K12, 45H4
γ_1	1.33	s	46P1
	1.35	s	43M3
	1.34	a	45H4
γ_2	0.98	s	46P1

Probably softer γ's 46P1
K X-ray 45H4
γ/e^- ~14 45H4
See also Ti^{48}

V-n-α	chem	45H4
Ca-p-n	chem	45H4
Ti-n-p	chem	45H4
Ca-d-2n	chem	45H4
Ti-d-α		44H3

$^{49}_{21}Sc_{28}$

τ	57^m		47S33, 40W1
	1^h		49D18
β^-	2.4	a	49D18
	1.8	a	37W6
No γ			40W1
Ca-d-n	chem		37W6, 40W1
Ti-n-p	chem		37P2, 40W1
Ti-γ-p	relσ		49H4
	d 8.5^{m}Ca		49D11

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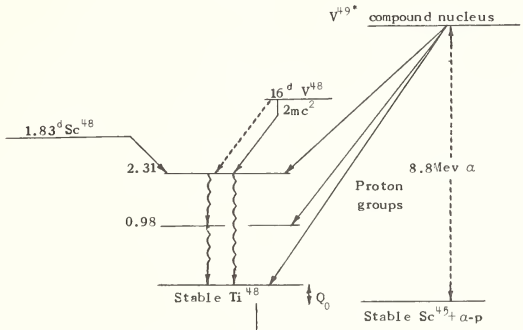
Neutron Cross Sections for Natural Element				43 (22 21)			44 (22 22)		
σ_s coh	1.8	(-)	49S12	τ	0.58^s	48S20	τ	$<1^m$ or $>100^y$ from Sc-d	49B55
σ_s bound	~6		49S12						
	$E_n = 0.025$ev								
σ_a	5.8		49P3						
	5.9		49H2						
$\sigma_s(TiO_2)$	14		37G1						
$\sigma_t(TiO_2)$	28		46D13						
Values at other energies 46D13, 49H16									
	$E_n = 2.5$Mev								
σ_t	1.7		39A5						
	Graphs Available								
σ_t	0.1-1.4Mev		50Ad	Ca-α-n		48S20			

45 (22 23)				46 (22 24)			47 (22 25)		
τ	3.08^h		41A2		7.95%	38N2		7.75%	38N2
	3.1		48W13		8.22	49H38		7.42	49H38
β^+	1.2	cc	41A2						
(19)*	1.00	s	49K36						
γ (4)*	0.48	s	49K36						
(1)*	0.80	s	49K36	Levels	0.89	Sc^{46}			
					2.01				
3.1^d activity reported from Sc-p-n (given as 21^d due to typographical error) probably attributable to 80^hZr from Y impurity.			49D3						
* relative intensities									
Ca-α-n	chem		41A2						
Sc-p-n	chem								
Sc-d-2n	chem								
Ti-n-2n									
Ti-γ-n	relσ		48W13						

48
22 26

73.45% 38N2
73.38 49H38



Sc-α-p

$Q_0 = -0.3$
$Q_1 = -1.4$
$Q_2 = -2.6$ } 38P6

49
22 27

5.51% 38N2
5.56 49H38

50
22 28

5.34% 38N2
5.41 49H38

σ's
(th n,γ) 6^mTi 0.14 47S33

51
22 29

τ	6^m		47S33, 49S13
β^-	1.6	a	47S33, 49S13
γ			37W3
Ti-n-γ	σ		47S33
Ti-d-p			37W3

72^d activity previously assigned here not found by Ti-n-γ 49D11

Neutron Cross Sections for Natural Element

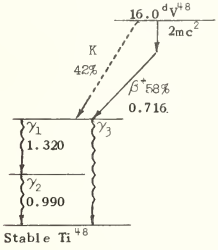
σ_s coh	<0.1	49S12
σ_s bound	5	49S12
	$E_n = 0.025$ev	
σ_a	4.7	49P3
	5.6	49H2
σ_s	<4	37G1
σ_t (V_2O_5)	40	46D13
	Resonance	
E_o		
3370 ev		47L18

$^{47}_{23}V_{24}$

τ	33^m		37W3, 4201
β^+	1.65	a	49K12
	1.8	a	4201
	2.0	a	37W3(46B27)
γ			49K12
Ti^{47}-p-n			49K12
Ti-d-n	chem		37W3
Ti-p-n	chem		4201
Not produced by Ti-α, Sc-α, V-n-2n			49K12

$^{48}_{23}V_{25}$

τ	16.0^d		37W3
K 42%			46G1
β^+ 58%			46G1
	0.716	s	46P1
	1.0	cc, a	37W3
γ_1	1.320	s	49R4
	1.33	s	46P1
γ_2	0.990	s	49R4
	0.98	s	46P1
	1.0	cc	38R2
γ_3	$1.63<E_\gamma<2.3$ in 1% of disintegrations		49F5



See also Ti^{48}

$\gamma/\beta^+ = 2$		46P1
$\gamma/\beta^+ = 4$		38R2
Sc-α-n	chem	37W3
Ti-d-n	chem	37W3, 44H3
Ti-p-n		44D9
Cr-d-α	chem	37W3, 46P1

$^{49}_{23}V_{26}$

τ	600^d		39W1
K			39W1
No β^+			39W1
No γ, no e^-			39W1
Ti-d-n	chem		39W1

50		
23 27		
	0.25%	49H33
	0.23	49L13
No vanadium X or γ activity of $\sim 4^h$ found from Ti-d, Ti-α, V-fast n or Ti-p. Activity of this period previously reported by 37W3 and 40A3 possibly due to Sc^{44}.		49K12

51			
23 28			
	~100%		24A1
I	7/2	S	36K4
μ	5.15	I	49K24
Levels	0.267		Cr^{51}
	0.320		Cr^{51}
	1.1	Ti-α-p	38D7
	4.7	Ti-α-p	38D7
	σ's		
(th n, γ) 3.7^mV		4.5	47S33
(~1Mev n, γ) 3.7^mV		2.2mb	49H5
Other fast n values			48WH
(1.6Mev p, n) 26^dCr		10mb	48S29
Ti-α-p			38D7
Q = 1.10, 0.00, -3.83			38D7

52			
23 29			
τ	3.74^m		47M17
	3.9		37W3
β^-	1.98	a	40G3
	2.7	cc	42Y1
γ	1.45	a	47M17
	1.44		42K8
See also Mn^{52}			
γ/β = 0.65			47B20
= 0.36			47M17
$\beta\gamma/\beta$ independent of β energy			47B20
Evidence for ~0.25Mev e^-'s not in coincidence with β's or γ's			47B20
Levels ?	2.47	V-d-p	39D7
	4.70	V-d-p	39D7
V-n-γ	σ		47S33
V-d-p			39D7, 37W3
Q = 7.80, 5.33, 3.10			39D7
Cr-n-p			37W3, 37P2
Cr-γ-p	relσ		47H4
Mn-n-α			37W3, 37P2

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev		
σ_a	2.8	49P3
	3.1	49H2
σ_s	~3.6	37G1
σ_t	7.3	47GIF
Values at other energies		49H16
Resonances		
E_o		
115-300ev		49H16
4,200		49H18
E_n~2.8Mev		
σ_t	3.4	39A5
Other fast n values		48WH
Graphs Available		
σ_t	0.01-1000ev	47GIF, 50Ad

49 (24 25)

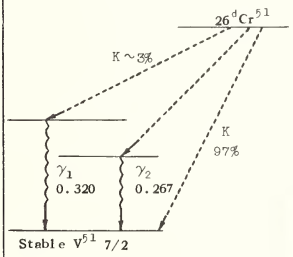
τ	41.9^m		4201
	45		48W13
	40		49H29
β^+	1.45	a, cc	4201
γ	0.19	a	4201
	1.55	a	4201
γ's ~equal intensity			4201
Tl-α-n	chem		4201
Cr-n-2n	chem		4201
Cr-γ-n	relσ		49P5, 48W13

50 (24 26)

	4.41%	49H3
	4.31	48W9
	4.49	39N2
σ's		
(th n,γ) 26.5^dCr	11	47S33
(th n,γ)	16.3	49P4

51 (24 27)

τ	26.5^d		40W3
	26		48H4
	25		49H29
K			45B1
No β^+			45B1, 48K10
γ_1	0.320	s	48K10, 46M6
	0.323	sc	49K14
~3%	0.330	sc	45B1
	α_K ~0.02		45B1
γ_2	0.267	sc	49K14
	0.237	sc	45B1
	$\alpha = \infty$		45B1
V K_α X-ray			45B1, 40W3
Tl-α-n	chem		40W3
Cr-d-p	chem		40W3
Cr-n-γ	σ		47S33
V-p-n	chem		45B1
	σ	Q = -1.534	48S29



52 (24 28)

	83.46%	49H3
	83.76	48W9
	83.78	39N2
Levels	1.46	Mn^{52}, V^{52}
	2.40	Mn^{52}
	3.13	Mn^{52}
See Mn^{52} for diagram		
σ's		
(th n,γ)	0.73	49P4

53 24 29	54 24 30	55 24 31
9.54% 49H3 9.55 48W9 9.43 39N2	2.61% 49H3 2.38 48W9 2.30 39N2	τ 1.3^{h} 47S33 1.6 40A3 2.3 40D2
	Level 0.835 Mn^{54}	
σ's (th n,γ) 17.5 49P4	σ's (th n,γ) $\leqslant$0.3 49P4 (th n,γ) 1.3^{h}Cr 0.006 47S33	
		Cr-n-γ chem 40D2 σ 47S33 Cr-d-p chem 40A3

Neutron Cross Sections for Natural Element

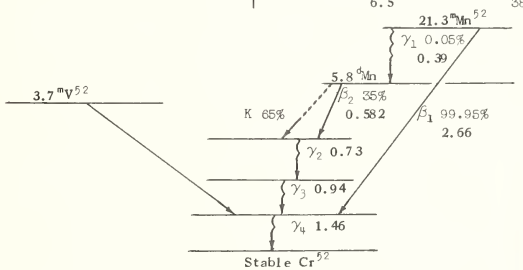
σ_s coh	1.3	(-)	49S12
σ_s bound	2.2		49S12
$E_n = 0.025$ev			
σ_a	12.8		49P3
	12.5		49H2
σ_s	2.3		(48WH)
σ_t	15.5		(48WH)
Values at other energies			49H16
Resonances			
E_o	σ_o	Γ	
300 ev	~5,000	~10	49S1
Scattering resonance			49S1
$E_n \sim 2.5$Mev			
σ_t	~3		39A5
Other fast n values			48WH
Graph Available			
σ_t	0.015-5,000ev		47RG, 47GIF

51
25 26

τ	46^m		38L1
	45		48M12
β^+	2.4	a	38L1(46B27)
Cr-d-n	chem		38L1
Cr-p-γ	chem		39D1
Cu-d	chem		48M12

52
25 27

τ_1	21.3^m	40H1	τ_2	5.8^d	48M20
	21	38L1		6.2	49H29
				6.5	38L1



Order of γ_2, γ_3 not established 46P1

21.3^mMn produced by

Cr-d-2n	chem	46P1
Cr-p-n	chem, rel σ	40H1
threshold ~8.3		40H1
Fe-d-α	chem	38L1
d 7.8^{h}Fe		48M12

5.8^dMn produced by

Cr-d-2n	chem	46P1
Cr-p-n	yield	46C9
threshold = 8		46C9
Cr-p-n	chem, rel σ	40H1
threshold ~6.3		40H1
Fe-d-α	chem	38L1

21.3^mMn

β_1^+	99.95%	2.66	s	4701
γ_1	0.05%	0.39	sc	4701

5.8^dMn

K	65%			46G1
β_2^+	35%			46G1
		0.582	s	46P1
γ_2		0.734	s	46P1
γ_3		0.94	s	46P1
γ_4		1.46	s	46P1

53
25 28

54
25 29

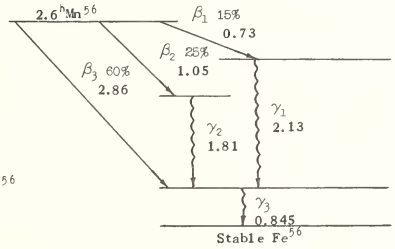
τ	310^d		38L1
K			38A2
No β^+			49K16
β^- <0.1%	1.0	cc	49K16
γ	0.835	s	44D1
	0.85	a	38L1
Not identical with 0.845γ of Mn^{56}			43E4
Cr K_α (?) X-ray			38A2
Xγ coincidences			44D1
V-α-n			38L1
Cr-d-n	chem		38L1
Cr-p-n			44D9
Fe-d-α	chem		38L1
Mn-γ-n			49H17
threshold = 10.2			49H17

55
25 30

	100%		36S4
I	5/2	S	30W1, 39F3
μ	3.0	S	39F3
	σ's		
(th n,γ) 2.6^hMn	13.0		44D10
($\sim$1Mev n,γ) 2.6^hMn	3.5mb		49H5
Other fast n values			48WH, 49B4
(1.2Mev p,n) 4^yFe	0.5mb		48S29

56
25 31

τ	2.59^h		38L1
	2.62		48P3



See also Co^{56}

$\gamma \sim 2.7$Mev in $\sim$0.23% of disintegrations 47L23

Levels of Mn^{56} at 1.07, 1.77, 2.48, 3.61, 4.38 from Mn-d-p, assuming most energetic protons go to ground state. 47M26

Mn-n-γ	σ	44D10	Co-n-α	chem	38L1
Mn-d-p	chem	38L1	Cr-α-p	chem	37R1
Fe-d-α	chem	38L1	Mn-n-γ		49K15
Fe-γ-p	rel σ	48P3	E_γ(max) = 8.9		49K15
Fe-n-p	chem	38L1			

β_1^- 15%	0.73	s	43E4
20%	0.75	s	46S2
β_2^- 25%	1.05	s	43E4
30%	1.04	s	46S2
β_3^- 60%	2.86	s	43E4
50%	2.81	s	46S2
γ_1	2.13	s	43E4
	2.06	s	46S2
12.5%*	2.11		42K8
γ_2	1.81	s	43E4
	1.77	s	46S2
18.75%*	1.83		42K8
γ_3	0.845	s	43E4
	0.822	s	46S2
68.75%*	0.866		42K8
Not identical with 0.835γ of Mn^{54}			43E4

* relative %

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Neutron Cross Sections for Natural Element		
σ_s coh	10.3	49S12
σ_s bound	11.4	49S12
	$E_n = 0.025$ev	
σ_a	2.39	49P3
	2.46	49H2
σ_s	11	(48WH)
σ_t	13	(48WH)
	$E_n = 1$Mev	
σ_t	~2.5	See graphs
	Graphs Available	
σ_t	0.013-1,000 ev	48H46
	0.013-2,000 ev	50Ad, 49H18
	0.025-15 Mev	47GIF
	0.02-0.5 Mev	48B24
	0.02-1.4 Mev	50Ad
	1-40 Mev	50Ad

51 (26 25)		

52 (26 26)		
τ	7.8^h	48M12
β^+	~0.55 a	48M12
Cu-d	chem, rel σ	48M12
p	21^mMn	48M12

53 (26 27)		
τ	8.9^m	44H5, 38L6
β^+		49P5
Fe-γ-n	rel σ	49P5, 48W13
threshold = 13.8		49M17
	14.2	45B12
Cr-α-n	chem	38L6
Fe-n-2n	chem	38L6

54 (26 28)		
	5.90%	49H3
	5.81	48W9

55 (26 29)		
τ	2.91^y	49B35
	~4	48V8
K		46B5
No β^+ or e^-		46B5
2×10^{-5} γ's with average energy 0.07 per disintegration		46B5
No γ		46P4
Mn K X-ray		46B5
Levels	0.935	Co^{55}
	1.41	
Mn-p-n	chem	46B5
	σ, Q = -1.16	48S29
Mn-d-2n		48H35
Fe-d-p	chem	39L8
d	18.2^hCo	41L1

$^{56}_{26}Fe_{30}$

	91.52%	49H3
	91.64	48W9
Levels	0.845	Mn^{56}, Co^{56}
	2.66	Mn^{56}
	2.98	Mn^{56}
	Others ?	Co^{56}

$^{57}_{26}Fe_{31}$

	2.245%		49H3
	2.21		48W9
μ	~0	S	49B20, 49G6
Levels	0.014		Co^{57}
	0.131		
Fe-n-γ			49K15
E_γ (max) = 7.8			

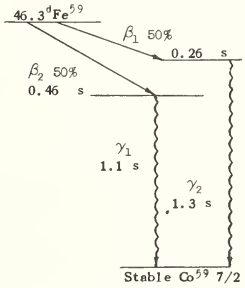
$^{58}_{26}Fe_{32}$

	0.33%	49H3
	0.34	48W9
Level	0.81	Co^{58}
	σ's	
(th n, γ) 47^dFe	0.36	47S33
	0.83	48O4
(th n, α)	$\leqslant$1.5mb	44H6

$^{59}_{26}Fe_{33}$

τ	46.3^d	47S22
	45.5	43G3
	46	49H29

Probable decay scheme 42D1



Fe-n-γ	σ	47S33
Co-n-p	chem	38L6, 46I2
Co-d-2p		48T4
Fe-d-p	chem	38L6, 42D1
Cu-d	chem	48M12

$^{60}_{26}Fe_{34}$

Neutron Cross Sections for Natural Element

σ_s coh	1.76	49S12
σ_s bound	~5	49S12
$E_n = 0.025$ev		
σ_a	34	49P3
	36	49H2
σ_s	~5	37G1
σ_t	~41 Extrapolation	49B2

Resonances

E_o	σ_o	Γ	
108	12,500	2	49S1
115			47W8

Scattering resonance 47H23, 49S1, 49H16

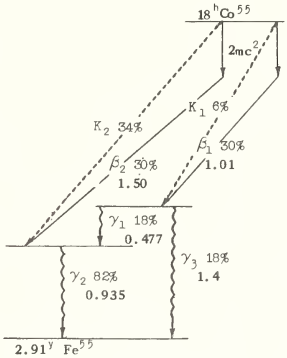
$E_n = 2.5$Mev		
σ_t	2.6	39A5

Graphs Available

σ_t	0.03-0.7ev	49B2
	0.15-10,000ev	47W8, 47GIF, 50Ad

55 — 27 28

τ	18.2^h	37D1
	18.0	41L1



Fe-d-n	chem	49D2
Fe-p-γ		41L1
	p 2.91^γFe	41L1

K_1	6%			49D2
K_2	34%			49D2
β_1^+	30%	1.01	s	49D2
β_2^+	30%	1.50	s	49D2
		1.50		39L6
γ_1	18%	0.477	s	49D2
		α~0.0025		49D2
γ_2	82%	0.935	s	49D2
		α~0.0004		49D2
	strong	0.8	cc	39C6
γ_3	18%	1.41	s	49D2
		α~0.0001		49D2
	weaker	1.2	cc	39C6
γ_4	weak	0.095	sc	49D2

Probably not in Co^{55} 49H34

$\beta\gamma$ coincidences support decay scheme. 49D2

56 — 27 29

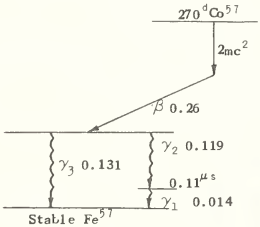
τ	80^d		42C1
	72		41L1
β^+	1.50	s	43E2
γ 1.0*	0.845	s	43E2
0.5	1.26	s	
0.2	1.74	s	
0.1	2.01	s	
0.2	2.55	s	
0.2	3.25	s	

* Relative intensities

Fe-d-2n		41L1
threshold > 5.5		41L1
Fe-α-np		41L1
Ni-d-α		42C1

57 — 27 30

τ	270^d	41L1



Fe-d-n	chem	41L1
Fe-p-γ		41L1

β^+	0.26		41L1
γ_1	0.014		49H34
	$0.11^{\mu s}$ delay		
	$\alpha < \infty$		
γ_2	0.119	s	43E4
	0.117	s	42P1
	α_K~1	K/L = 7	42P1
γ_3	0.131	s	43E4
	0.130	s	42P1
	α_K~1	K/L = 7	42P1

Level in Co^{57} 1.97 ? Ni^{57}

$^{58}_{27}Co_{31}$

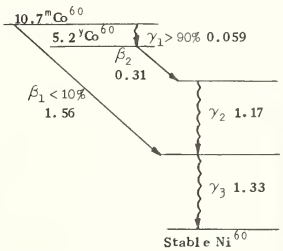
τ_1	9.3^h	49S29	τ_2	72^d		41L1
IT		49S29	K	85.5%		46G1
γ	0.023	49S29	β^+	14.5%		46G1
				0.47		44D1
			γ	0.81		44D1
			Mn-α-n			41L1
			Fe-d-n			41L1
			Fe-α-pn			41L1
			Fe-p-γ			41L1
			Ni-n-p	chem		44D1

$^{59}_{27}Co_{32}$

	100%		41M5
I	7/2	S	35K5, 34M2
μ	2.7	S	35M7
Levels	1.1		Fe^{59}
	1.3		
	σ's		
(th n, γ) 10.7^mCo	0.66		47S33
(th n, γ) 5.3^yCo	22		47S33
(1Mev n, γ) 10.7^mCo	0.23mb		49H5

$^{60}_{27}Co_{33}$

τ_1	10.7^m		41L1



Angular correlation of γ's consistent with I = 4, 2, 0 — 48B18

$10.7^m Co^{60}$ produced by

Co-n-γ	σ	47S33
Co-d-p	chem	45D1
Ni-n-p		41L1, 37H3

τ_2	5.2^y		49B35
	5.3		41L1
$10.7^m Co^{60}$			
β_1 <10%	1.56	s	47P10
	1.35	s	42N1
	1.25	s	45D1
γ_1 >90%	0.0589	sc	49C1
	0.056	s	45D1
$5.2^y Co^{60}$			
β_2	0.31	s	47M10, 45D1
γ_2	1.172	s	49H23, 49L8
	1.169	s	49J2
	1.16	s	47P10, 47M10
γ_3	1.332	s	49L8
	1.331	s	49J2, 49H23
	1.32	s	47P10, 47M10

Cross-over γ's per disintegration
$<2\times10^{-6}$ — 49M8
$<2\times10^{-7}$ — 49F5

γ with $1.63<E<2.3$ per 10^5 disintegrations — 49F5

Lifetime of γ's $<2\times10^{-9}$ s — 49D22
$<3\times10^{-9}$ — 49B39

No $\beta\gamma$ angular correlation — 49G21

$5.2^y Co^{60}$ produced by

Co-n-γ	σ	47S33
E_γ (max) = 7.7		49K15
Co-d-p	chem	45D1
Ni-d-α		41L1
Cu-n-α		46M4

61 27 34				62 27 35						
τ	1.75^{h}		49P1	τ_1	13.9^{m}		49P1	τ_2	1.6^{m}	49P1
	1.74		48P3							
	1.83		49H20							
β^-	1.3	a	49P1	β^-	2.3	a	49P1	β^-		49P1
No γ			49P1	γ	1.3	a	49P1	γ		49P1
				$\beta/\gamma \sim 1$			49P1			
Ni-d-2n	ms									
Ni^{61}-n-p	chem			Ni^{62}-n-p	chem		49P1	Ni^{62}-n-p		49P1
Ni^{64}-p-α	chem		49P1					Ni^{64}-d-α		49P1
Ni^{64}-d-αn	chem									
Cu-n-nα	chem									
Ni-γ-p	relσ		48P3							
Cu-γ-2p	relσ		48P3							

63 27 36				64 27 37						
				τ	4-5^{m}		49P1			
				Ni^{64}-n-p			49P1			

Neutron Cross Sections for Natural Element

σ_s coh	13.5	49S12
σ_s bound	17.2	49S12
E_n = 0.025ev		
σ_a	4.5	49P3,49H2
σ_s	17.5	47T14
σ_t	~18.5 ce	48H46
Resonance		
E_0		
3600ev		49H18
E_n = 1Mev		
σ_t	~3.5	47GIF,50Ad
Graphs Available		
σ_t 0.01-1000ev		48H46
0.01-3000ev		50Ad
See also		49H16
0.01-10Mev		47GIF
0.01-0.5Mev		48B24
0.01-1.5Mev		50Ad

See also Ni^{58} and Ni^{60}

57 (28 29)

τ	36^h		49M38,38L3
	37		44H5
	34		48H4
β^+	0.73	a	49M38
	0.67	a	38L3
γ	1.97	a coin	49M38
	1.9	a, scin, γn	50F2
$\gamma\gamma$ coincidences indicate 2 γ's in cascade.			49M38
$\beta\gamma$ coincidences indicate only one β.			49M38
Coincidences between hard γ and annihilation γ			50F2
Co K X-ray			50F2
Fe-α-n	chem		50F2,49M38,42N2
Ni-n-2n	chem		42N2
Ni-γ-n	relσ		49P5,48P3,44H5
threshold = 11.7			49O2

58 (28 30)

	67.76%	48W9
	67.92	48I6
	69.18	48E6
σ's		
(th n,γ)	4.2	49P4
σ_t graph 0.025-0.5ev		49B2
Big σ_s due to this isotope		
σ_s coh	26	49S12
σ_s bound	25	49S12

59 (28 31)

τ	$(2-3)\times10^5{}^y$	49F6
	1.5×10^5	49B38
Both results from yield measurements		
K		49F6,48B13
No β^-		48B13
Co K X-ray		49F6
Ni^{58}-n-γ	chem	49F6
Co-d-2n	chem	48B13
Ni-n-γ		48B13

60 (28 32)

	26.16%	48W9
	26.22	48I6
	25.82	48E6
Levels	1.33	Co^{60}
	1.5	Cu^{60}
	2.50	Co^{60}
σ's		
(th n,γ)	2.7	49P4
σ_t graph 0.025-0.5ev		49B2
σ_s coh	1.0	49S12
σ_s bound	1.0	49S12

61 (28 33)

	1.25%	48W9
	1.16	48I6
	0.97	48E6
σ's		
(th n,γ)	1.8	49P4
(6.1Mev p,n)3.4^{h}Cu	0.11	38S5

62
28 34

	3.66%	48W9
	3.71	48I6
	3.28	48E6
Levels	0.6	Cu^{62}
	1.3	Co^{62}
σ's		
(th n,γ)	14.8	49P4
(6.1Mev p,n)10^{m}Cu	0.15	38S5

63
28 35

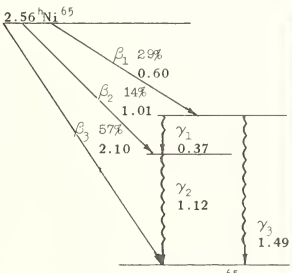
τ	85^{y}		49B38
	From yield		
β^-	0.063	pc	49W10
	~0.05	a	49F6
	0.05	a	48B13
No β^+			49W10
No γ observed (<1%)			49F6,49W10
Ni^{62}-n-γ	chem		49F6,48B13
Ni-n-γ	chem		49W10,48F4

64
28 36

	1.16%	48W9
	0.98	48I6
	0.75	48E6
Level	1.34	Cu^{64}
σ's		
(th n,γ)2.6^{h}Ni	2.6	46H32
	1.5	47S33
(~1Mev n,γ)2.6^{h}Ni	6.7mb	49H5

65
28 37

τ	2.564^{h}			49S2
	2.6			49M38,48H4,38L3
Proposed decay scheme				49S21
β_1 29%	0.60	s		49S21
	0.44	a$\beta\gamma$		49M38
β_2 14%	1.01	s		49S21
β_3 57%	2.10	s		49S21
	1.97	a		49M38
	1.9	a		46S8,38L3
γ_1	0.37	s		49S21
γ_2	1.12	s		49S21
γ_3	1.49	s		49S21
	1.64	a		49M38
γ's	0.280, 0.65, 0.93	s		41G1
$\beta\gamma$, $\gamma\gamma$ coincidences support decay scheme				49M38,49S21
Cu^{65}-n-p	chem			46S8
Ni^{64}-n-γ				46C3,46G15
Ni-n-γ	chem			42N2
Zn-n-α				37H3
Ni-d-p				42N2



66
28 38

τ	56^{h}	48H4,48G1
β^-		48G1
B1 fission		48G1
As-d		48H4
p 4.34^{m}Cu		49G13,48G1

Neutron Cross Sections for Natural Element

σ_s coh	7.3	49S12
σ_s bound	7.7	49S12
	$E_n = 0.025$ev	
σ_a	3.66	49P3
	3.63	49H2
σ_s	7	(48WH)
σ_t	~11 ce	48H46
	Resonance	
E_o		
3,000 ev ?		48H46
570		47L18
Scattering resonance 500-1000 ev,		48H57
140 (12^hCu), 100 (5^mCu)		48C24
	Graphs Available	
σ_t	0.015-10,000 ev	50Ad, 48H46
	0.015-100 ev	47GIF
	See also	49H16
	0.025-14 Mev	47GIF
	0.2-1.5 Mev	50Ad

$^{58}_{29}$?$_{29}$

τ	3^s	49A1
Ni^{58}-p		49A1

$^{59}_{29}$?$_{30}$

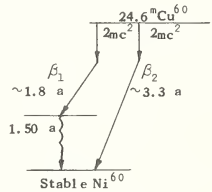
τ	10^m	47L7
	7.9	39D1
β^+		39D1
Ni-p-n	chem	39D1
Ni^{58}-p	chem	47L7
Ni-d		42C2

$^{59}_{29}$?$_{30}$

τ	81^s	47L7, 39D1
β^+		39D1
Ni-p-n	chem	39D1
Ni^{58}-p		47L7

$^{60}_{29}$$_{31}$

τ	24.6^m	47L7
	~20	48H4
Possible decay scheme		47L7



Ni^{60}-p-n	ms, chem	47L7
threshold = 5.1		
Ni^{60}-d-2n		
Ni^{58}-α-pn		

889592 O - 50 - 9

61
29 32

τ	3.33^h		48C8
	3.3		48H4
	3.4		49B16, 37T1, 37R1
K			49B16, 38A2
β^+	1.205	s	48C8
	1.225	s	45B2
$K/\beta^+ = 0.32$			49H21
0.55			49B16
No γ			45B2, 38G1
Spectral shape			49O4
β spectrum probably complex			50B4
Ni^{61}-p-n			47L7
Ni-p-n	σ		38S5
threshold > 3			38S5
threshold = 2.7			39D1
Ni-d-n	chem		37T1
Ni-α-p	chem		37R1
Cu-γ-2n	rel σ		48P3
Ni-p-γ	chem		39D1

62
29 33

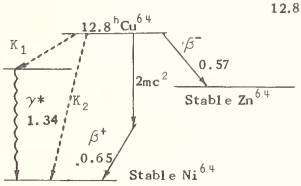
τ	9.9^m		49P15, 48P3
	10.1		47L7
	10.5		37H3
β^+	2.83	s	49B17
	2.92	s	49H42
	2.92	a	50K1
γ	0.56	a	47T3
Ni^{62}-p-n			47L7
Cu-γ-n	rel σ		48P3
threshold = 10.9			45B12, 49M17
Ni-p-n	σ, f		38S5
Ni-p-γ	threshold < 3		38S5
Co-α-n	chem		37R1
Cu-n-2n	chem		37H3
threshold ~ 12			40S10, 38S14
threshold = 11.2, σ			49F14
Cu-e^--e^-n	f		48S3
Cu-d-t	Q = 5.2		46M7
d 9.5^h Zn			48M12

63
29 34

	69.09%		48H40
	68.94		48W9
	68.39		44E1(48H40)
	67.66		47D13(48H40)
I	3/2		32R2
μ	2.2215		49Po
		I	49B7, 49Z2, 48P11
Q	-0.1	S	36S7
Levels	0.96		Zn^{63}
	1.89		
	2.60		
σ's			
(th n, γ) 12.8^hCu	2.8		47S33
(th n, γ)	4.3		49P4
(1Mev n, γ) 12.8^hCu	0.009		49H5
(14Mev n, 2n) 10^mCu	0.48		49F14
	0.32		49P15
For other fast n values			see 48WH, 49B4
(6.1Mev p, n) 38^mZn	0.093		38S5
(14Mev d, 2n) 38^mZn	0.30		46C5

64
29 35

τ	12.88^h		49S2
	12.8		48W13, 36V2



* Coincidence measurements show this line follows K capture 46B3

Ni-p-n	chem, σ		39D1, 38S5
threshold = 2.1-2.3			39D1
2.5			38S5
Zn-n-p	chem		37H3
Cu-d-p			36V2
Cu-n-2n			37H3
Cu-n-γ	E_γ(max) = 7.7		49K15
Cu-p-pn	threshold ~ 13		46R2
Cu-γ-n			44H5
threshold = 10.2			49M17
	rel σ		48W13, 49P5
K			38A2
β^+	0.657	s	48C2
	0.644	s	47P10
	0.659	s	46B3
β^-	0.571	s	48C2
	0.570	s	47P10
	0.578	s	46B3
γ	1.34	s	48K10
	$\alpha < 5\times10^{-3}$		48M26
	1.35	s	47D7
	1.20	a coin	46B3
Spectral shapes			49W1
β^-/β^+	2.08		47P10
	2.0		48C2, 49B16
	2.1		46B3
K/β^+	2.65		49B16
	1.75		49H21
	3.5		48C14
γ/β^+	0.05		49B16
Ni K_α, K_β X-rays			49C4

65
29 36

	30.91%		48H40
	31.06		48W9
	32.34		47D13(48H40)
	31.61		44E1(48H40)
I	3/2		32R2
μ	2.3796		49Po
		I	49B7, 49Z2, 48P11
q	-0.1		36S7
Levels	1.12		Ni^{65}, Zn^{65}
	1.49		Ni^{65}
σ's			
(th n,γ)	2.1		49P4
(th n,γ)4.3^{m}Cu	1.8		47S33
(1Mev n,γ)4.3^{m}Cu	0.006		49H5
For other fast n values see			49B4, 48WH
(14Mev d,2n)250^{d}Zn	0.51		46C5

66
29 37

τ	4.34^m		49S2
	5.05		46M7
β^-	2.58		40G3
	2.9	cc,KU	38S1
γ	1.32	a	46M7
Cu-n-γ	σ		47S33
Cu-d-p			46M7
Zn-n-p			37H3
Ga-n-α			37C1
d 56^{h}Ni			49G13, 48G1

67
29 38

τ	56^h		49G13
	61		48H4
β^-	0.5	a	49G13
Bi fission			49G13
As-d			48H4

Neutron Cross Sections for Natural Element

σ_s coh	4.3	49S12
σ_s bound	4.2	49S12
$E_n = 0.025$ev		
σ_a	1.0	49P3
	1.1	49H2
σ_s	3.6	(48WH)
σ_t	4.5	(48WH)
Resonances		
E_o	>300ev	49H16
	480 strong	48H45
	800 possible	48H45
	3100	48H45
	14000	48H45
480ev resonance assigned to $Zn^{68}(n,\gamma)52^mZn^{69}$ $\Gamma\sim4$		48C24
Scattering resonances observed		48H57
$E_n = 1$Mev		
σ_t	~4	See graphs

Graphs Available

σ_t	0.001-2000ev	50Ad,47GIF
	0.02-11Mev	47GIF
	0.02-1.5Mev	50Ad
	1-80Mev	50Ad

Other references on graphs and in 48WH

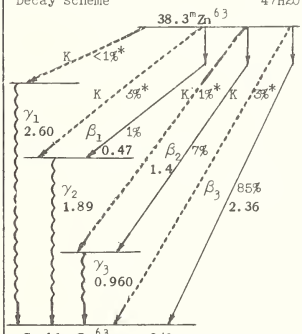
62
30 32

τ	9.5^h		48M12
	9.2		49H42
	10		49H14
K 90%			49H42
β^+ 10%	0.665	s	49H42
γ	0.0418	s	49H42
Cu-d-3n or Cu-d-5n	chem		48M12
Zn-γ-2n	relσ		49H44
p 9.9^mCu			48M12

63
30 33

τ	38.3^m		48W13,38S5
	38		39B5,39D1
	39		49H14

Decay scheme 47H20



* % calculated from Fermi theory for allowed transitions. K capture observed in 5-10% of disintegrations 47H20

β_1^+	1%	0.47	s	47H20
β_2^+	7%	1.40	s	47H20
β_3^+	85%	2.36	s	47H20
		2.3	s	41T1
		2.3	a	39D1(46B27), 38S5
γ_1		2.60	s	47H20
γ_2		1.89	s	47H20
γ_3		0.960	sc	47H20
		$\alpha\sim1.8\times10^{-4}$		47H20
Cu K X-ray				47H20

Hard secondary γ found from absorption of β^+ in Pb. Ascribed to hard annihilation γ since intensity is greater than expected intensity from bremsstrahlung 47H20

Zn-n-2n	chem	37H3,37P2
threshold 9-10		38S14
Cu-p-n	f	39D1,38S5
threshold = 4.1		38S5
3.8		39D1
Ni-α-n		37R1
Zn-γ-n	relσ	49H44,49P5,48W13
threshold = 11.8		49H17
11.6		45B12
Cu-d-2n	f	46C5
threshold = 6.5		46C9
~7		40L4
	rel yield	48M12

64
30 34

48.87%		49H3
48.89		48L5,48H40

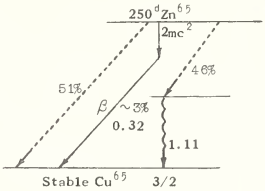
Possible levels or level groups from n groups in Cu-d-n 49G5

σ's

(th n,γ)250^{d}Zn	0.51	47S33
(th n,p)12.8^{h}Cu	$< 10^{-5}$	49M27

65
30 35

τ	250^d		39L2
	long		49H14



β^+ 2.8%			47Z2
2.2			46G2
	0.32	s	47P10
γ 46%	1.11	s	49J2
	1.14	s	42D3,43M4

Cu X-ray 38A2

$X\gamma$ coincidences show 46% of K captures go to 1.11 level 46G2

γ's of 0.45, 0.65, and 1.0 cc 40W4

Zn-d-p	chem	39L2
Zn-n-γ	chem	39S2
	σ	47S33
Cu-p-n	chem	39L2
threshold = 2.16		48S33
Cu-d-2n	chem	39L2,38P1
	f	46C5
	yield	46C9
threshold = 4.6		46C9

66
30 36

27.62%		49H3
27.81		48L5
27.82		48H40

Possible levels or level groups from n groups in Cu-d-n 49G5

Level 1.32 Cu^{66}

σ's

(~4Mev n,p)4.3^{m}Cu	3.7mb	40D8

67
30 37

	4.12%		49H3
	4.07		48L5
	4.14		48H40
I	5/2	S	37L7,48A6
μ	0.9	S	37L7

Levels 0.093 Ga^{67}
0.390
0.570

68
30 38

18.71%		49H3
18.61		48L5
18.54		48H40

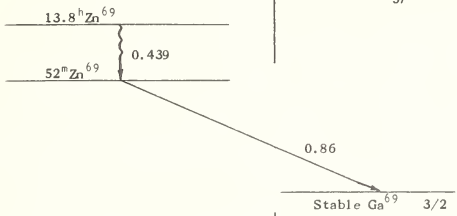
σ's

(th n,γ)13.8^{h}Zn	0.89	49H5
(th n,γ)52^{m}Zn	0.085	49H5
(~1Mev n,γ)13.8^{h}Zn	0.007	49H5
(~1Mev n,γ)52^{m}Zn	0.013	49H5

E_o (n,γ)52^{m}Zn = 500ev		48C24
Γ = 1.7-5.5ev		48C24

69
30 39

τ_1	13.8^h	39L2	τ_2	52^m	49H17
	14	48H4		51	48H4
				57	39L2



γ	0.439	sc	41H1,41G1	β^-	0.86	a	39L2(46B27)
	$\alpha \sim 0.01$-0.1		41H1		1.0	a	39K4
	0.450		44N7				
	$\alpha = 0.06$		44N7				
No $\beta\gamma$ coincidences			39K4				
				Zn-d-p	chem		39K4
Zn-d-p	chem		39K4	Zn-n-γ	chem		39L2
Zn-n-γ	chem		39L2		σ		49H5
	σ		49H5	Ga-d-α	chem		39L2
Ga-d-α	chem		39L2	Ga-n-p	chem		39L2
Ga-n-p	chem		39L2	Zn^{70}-γ-n			49H17
				threshold = 9.2			49H17

70
30 40

	0.69%	49H3
	0.620	46L5
	0.617	48H40
	σ's	
(th n,γ)2.2^mZn	0.085	49H5
	0.086	46H25

71
30 41

τ	2.2^m	46H25
β^-	2.1	46H25
γ		46H25
Zn-n-γ	σ	46H25
Ge-n-α		46H25

72
30 42

τ	49^h		50s1
	~ 50		48H4
β^- 95%	0.3	a	50s1
5%	1.6	a	50s1
γ			50s1
Fission	chem		50s1
p 14.25^hGa			50s1

73
30 43

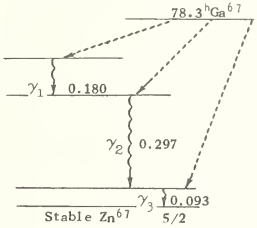
τ	$< 2^m$	50s1

Neutron Cross Sections for Natural Element			63 31 32
	$E_n = 0.025$ev		
σ_a	2.8	49P3	
	3.1	49H2	
σ_t	~19	42L1	
	Resonances		
	Scattering resonance in both isotopes in range 100-500ev	48H57	

64 31 33			65 31 34			66 31 35		
τ	48^m	38B4	τ	18.5^m	39V2	τ	9.4^h	38B4,37R1
							9.2	37M2
							10	48H4
β^+		38B4	γ	0.054 sc	39V2	β^+	3.9 a	37M2(46B27)
				0.117 sc	39V2			
			Assignment of 0.117γ to this activity doubtful		39V2			
Zn-p-n	chem,f	38B4	Zn-d-n	chem	39V2	Cu-α-n	chem,f	37M2,38B4
threshold = 4.1		38B4	Zn-p-γ		39V2	Zn-p-n		38B4
						(Not obtained with p's <3.5)		
						Zn-d-2n		42C2
						d 2.5^hGe		49H29

67
31 36

τ	78.3^h		48M32
	83		48H4,38A2



γ_1 weakest	0.180	s	41H1
	0.187	s	42C2
γ_2	0.297	s	41H1
	α=0.01		41H1
	0.302	s	42C2
	0.292	s	41G1
γ_3 strong	0.093	s	41H1
	α=2,K/L=8		41H1
	0.094	s	42C2

Additional γ of 0.174 found 42C2

Zn X-ray			38A2
Zn-d-n	chem		38G2,39V2
Zn-α-p	chem		38M1,48M32
Zn-p-n			39V2
Zn-d-2n			42C2
d 21^mGe			49H29

68
31 37

τ	68^m		37R1,48P3,48H4
β^+	1.9	a	37R1
	1.97	a	37M2
Cu-α-n	chem,f		37R1,37M2
Zn-p-n	chem,f		38B4
threshold = 3.7			38B4
Zn-d-n	chem		38G2,39V2
Ga-n-2n	chem		37P2
threshold = 6-7			38S14
Ga-γ-n			39B5
	rel yield		48P3
Ge-γ-pn	rel yield		49P5
Ge-d-α	chem		41S2
d 250^dGe			48H4

69
31 38

	60.2%		48I3
	60.0		49H3
I	3/2	S	32J1,33C2
		M	48B17
		Z	40R6
μ	2.012		48P9,48B17(49Po)
	2.11	Z	40R6
q	+0.2318		48B17(49D14)
	0.20		40R3
Level	1.22		Ge^{69}
	σ's		
(th n,γ)20^mGa	1.4		47S33
	1.5		49H5
(~1Mev n,γ)20^mGa	23mb		49H5

70
31 39

τ	20.3^m		47B13
	20		35A1,39B5.49H14
β^-	1.65	s	48H23
	1.62	a	47B13
	1.68	cc	39S9
γ			48H23
Zn-p-n	chem,f		40D1,39V2
threshold = 1.6			40D1
Zn-α-p	chem, rel yield		38M1
Ga-n-γ	σ		47S33
Ga-n-2n			37P2
Ga-γ-n			39B5
	rel yield		48P3
Ge-n-p	chem		41S2,45G2

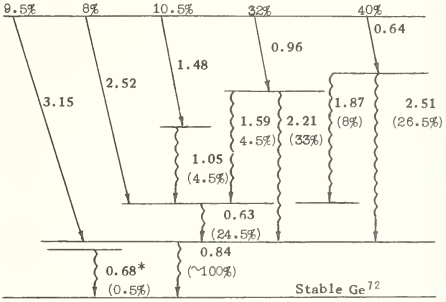
71
31 40

	39.8%		48I3
	40.0		49H3
I	3/2	S	32J1,33C2
		M	48B17
		Z	40R6
μ	2.556		48P9,48B17(49Po)
	2.69	Z	40R6
q	+0.1461		48B17(49D14)
	0.13		40R3
	σ's		
(th n,γ)14^hGa	3.4		47S33

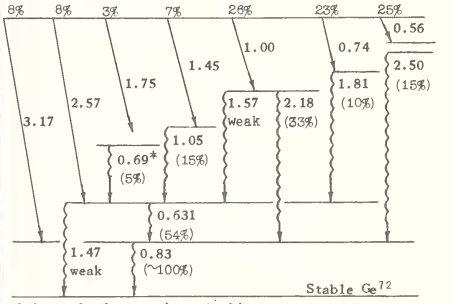
72
31 41

τ	14.25^h	50s1
	14.1	39G2

Decay scheme proposed from spectrometer results 48H23



Decay scheme proposed from spectrometer results 48M17



Figures in parentheses represent intensities relative to the 0.83 line

Ga-d-p	chem	38L6	Delayed βe^- coincidences for ~0.6 e^- and a β of ~1% intensity 48B10	$\beta\gamma$ coincidences	48J7
Ga-n-γ	chem	50s1		$\beta\gamma$ and $\gamma\gamma$ coincidences	47M29
	σ	47S33	$\tau = 0.5^{\mu s}$ No delayed γ's 48B10	Average γ energy per $\beta = 2.6$	47B22
Ge-n-p	chem	50s1,41S2		Only 2.51Mev γ produces D-γ-pn	49B25
Fission	chem	50s1,48SP	$\tau = 0.29^{\mu s}$ 49M29	*Only line converted	48M1,48H23
	d 49^hZn	50s1			

73
31 42

τ	5.0^h	50s1
β^-	1.4 a	50s1
No γ		50s1
Ge-n-p		50s1
Ge-γ-p	rel yield	49P5
Fission	chem	46PP
	d $<2^m$Zn ?	46PP

74
31 42

No long-lived activity produced by Ge^{76}-d-α 48M32

No Ga with $\tau > 1^d$ found in fission 50s1

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Neutron Cross Sections for Natural Element		
σ_s coh	8.5	49S12
σ_s bound	8.5	49S12
	$E_n = 0.025$ev	
σ_s	2.2	49P3
	3.5	49H2
σ_t	~6 ce	47W8
	Resonance	
E_o	$\sigma_o \Gamma^2$	
95ev	800	47W8
	Graphs Available	
σ_t	0.015-5000ev	47GIF,47W8

66 32 34		
τ	~2.5^h	49H29
Ge-d-p5n		49H29
p 9.4^{h}Ga		49H29

67 32 35		
τ	21^m	49H29
β^+		49H29
Ge-d-p4n		49H29
p 78.3^{h}Ga		49H29

68 32 36		
τ	250^d	49H29
	~195	38M1
K		48H4
Zn-α-2n	chem, yield	38M1
As-d-α5n	chem	48H4
Not produced by		
Ga-d		48M32
p 68^{m}Ga		48H4

69 32 37			
τ	39.6^h		48M32
	40		49H29
	36		44H5
K 67%			48M32
β^+ 33%	1.0	a	48M32
	1.22	a	38M1(46B27)
	1.2	a	41S3
γ	1.22	a	48M32
X-ray			48M32
This activity previously confused with 40^{h}As			
Ge-γ-n	rel yield		44H5
Ga-d-2n	chem		48M32
Zn-α-n	chem, yield		38M1
Ga-p-n			48D8
Ge-n-2n	chem		48M32,41S2
Not produced by			
Ge-d-p			48M32
Ge-n-γ			49M28
Not d 60^{h}As			49H14

70
32 38

	20.55%		47I13
	20.65		48H35
I	0	Mic	49T9
	σ's		
(th n,γ)11^{d}Ge	~0.5		47S33

71
32 39

τ	11.4^{d}		48H4,48M32
	11		49H29
K			44S5,48M32,49M28
No particles			44S5,47S33,48M32
No γ			48M32
Ga K X-ray			47S33,48M32
Ga-d-2n			48M32
Ge-d-p		chem	48M32
Ge-n-γ		σ	47S33
As-d-α2n		chem	48H4
Not found from Ge-γ-n			44H5
d 50^{h}As			48H27

72
32 40

	27.38%		47I13
	27.43		48H35
I	0	Mic	49T9
Levels	0.68		As^{72},Ga^{72}
	τ=0.29$^{\mu s}$		49M29
	0.83		Ga^{72}
	1.45		Ga^{72}
	others ?		As^{72},Ga^{72}

73
32 41

	7.61%		47I13
	7.86		48H35
I	9/2	Mic	49T9
q	-0.2	Mic	49T9
Levels	0.052		As^{73}
	0.1		

74
32 42

	36.74%		47I13
	36.34		48H35
I	0	Mic	49T9
Level	0.582 ?		As^{74}
	σ's		
(th n,γ)82^{m}Ge	0.4		47S33

75
32 43

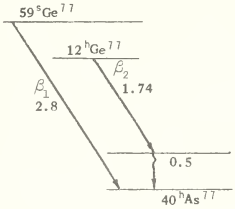
τ	82^{m}		48M32
	89		41S3
β^-	1.2	a	41S3
	1.1	cc	41S2
No γ			48M32
X-ray			41S3
Ge-n-γ		chem	41S2
Ge-d-p		chem	41S3,41S2
Ge-n-2n		chem	41S3,41S2
Ge-γ-n		rel yield	49P5,48W13, 44H5
As-n-p		chem	48M32
Se-n-α		chem	41S3,41S2

$^{76}_{32}Ge_{44}$

	7.67%		47I13
	7.72		48H35
I	0	Mic	49T9
σ's			
(th n,γ)59^{s}Ge	0.10		47A1
(th n,γ)12^{h}Ge	0.09		47S33

$^{77}_{32}Ge_{45}$

τ_1	59^{s}		47A1



No hard γ 47A1

^{59s}Ge produced by

Ge-n-γ	σ	47A1
p 40^{h}As		47A1

τ_2	12^{h}		41S3
	11		50S2
β_1^-	2.8	a	47A1
β_2^-	1.74	a	49M28
	2.0	a	50S2
	1.9	cc	41S2
γ	0.5	a	49M28
$\beta\gamma$ coincidences			49M28

^{12h}Ge produced by

Fission	chem	49G13
	chem	50S2
Ge-n-γ	chem	47A1
Ge-d-p	chem	41S2,41S3
Se-n-α	chem	41S3

Not produced by

As-fast n	41S3
Ge-fast n	41S3
p 40^{h}As	49M28,47A1

$^{78}_{32}Ge_{46}$

τ	2.1^{h}		50S2
β^-	~0.9	a	50S2
γ			50S2
Fission	chem		50S2
p 90^{m}As			50S2

No Ge with $\tau > 3^{d}$ found in fission 50W1

Neutron Cross Sections for Natural Element				68 33 35			69 33 36		
σ_s coh	5		49S12						
σ_s bound	7-8		49S12						
	$E_n = 0.025$ev								
σ_a	4.1		49P3						
	5.5		49H2						
σ_s	7.1		37G1						
σ_t	9		37F2						
Values at other energies			49H16						

70 33 37				71 33 38				72 33 39			
τ	52^m		48H4	τ	50^h		48M31, 39S10	τ	26^h		48H4, 48M31
					60		48H27				
β^+			48H4	K ~67%			48M31	K ~67%			48M31
				β^+~33%	0.6	a	41S2	β^+~33%	2.8	a	48M31
									2.8	a	47M11
									complex		47M11
								γ	0.6	a	48M31
									delay found		49G17
									1.4	a	48M31
									2.4	a coin	47M11
								See decay scheme of Ga^{72}			
As-d	chem		48H4	Ge-d-n	chem		48M31	Ga-α-n	chem		47M11
								Ge-p-n			48V8
								Se^{74}-d-α	chem		48M31
	d 44^mSe		48H4						d 9.7^dSe		48H4
	Not p active Ge		49H14		p 11^dGe		48M31				

73
33 40

τ	76^d		48M31
	90		39S10
	100		43E3
K			48M31, 43E3
No β^+			48M31
γ	0.052	sc	43E3
	α large, K/L = 5		43E3
	0.1	a	48M31
	$\alpha = 0$		48M31
Ge K X-ray			48M31
Ge^{70}-α-p			48M31
Ge-d-n	chem		43E3, 48M31

74
33 41

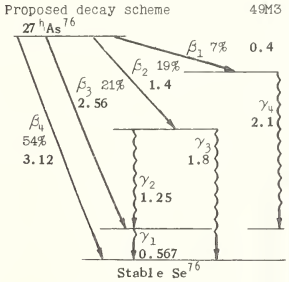
τ	17.5^d		48M31
	19.0		48H4
	16.8		48M33
K 35%			42E4
β^+ 35%	0.95	s	42E4
	0.9	cc	39S10
β^- 15%	0.72	s	42E4
	1.40	s	42E4
	1.3	cc	39S10
γ	0.588	s	42E4
	$\alpha \sim 0$		
	0.582	s	41D1
Follows K and β^+			42E4
Fission	chem		49G13
As-γ-n			48M33, 49O2
threshold = 10.3			49O2
As-n-2n	chem		38C3
Ga-α-n	chem		48M31
Ge-d-n	chem		48M31, 42I1
Ge-p-n			44D9
Se-d-α	chem		40F3

75
33 42

	100%		37N2
I	3/2 S		33C1, 32T1, 33R1
	Mic		48D8
μ	1.5 S		36S5
q	+0.3 S		36S5
Levels	several low		Se^{75}
	σ's		
(th n, γ) 27^hAs	4.2		47S33
(th n, γ)	4.1		49P3
	5.5		49H2
($\sim$1Mev n, γ) 27^hAs	0.023		49H5
For other fast n values see			49B4, 48WH

76
33 43

τ	26.8^h		42W1
	26.3		40M4
	26.1		48P8
Proposed decay scheme			49M3



As-n-γ	chem		48P8
	σ		47S33
As-d-p			38C3
Ge-p-n			48V8
Se-n-p	chem		39S10
Se-d-α	chem		40F3
Se-γ-p	relσ		47H4
Br-n-α			38C3

β_1^- 7%	0.4	s	49M3
β_2^- 19%	1.4	s	49M3
15%	1.29	s	47S9
β_3^- 21%	2.56	s	49M3
25%	2.49	s	47S9
β_4^- 54%	3.12	s	49M3
60%	3.04	s	47S9
γ_1	0.567	s	49M3
	0.557	s	48W2
	0.55	s	47S9
	0.57	s	46M6
γ_2	1.25	s	49M3, 46M6
	1.22	s	48W2
	1.20	s	47S9

γ_3 weak	1.78	s	48W2
	1.70	s	47S9
weak	1.84	s	46M6
γ_4 weak	2.15	s	46M6
Cross-over γ	$2.3 < E_\gamma < 2.76$		48M36
β^+/β^-	<0.1%		48W2
	<0.03%		47B8
	<0.5%		49M3
High $\gamma\gamma$ coincidence rate			40M4
Summary of early work			48P8

77 33 44	78 33 45	79 33 46
τ 40^h 50s2	τ 90^m 50s2 80 38C3 65 39S10	
β^- 0.7 a 50s2 No γ 49M28	β^- 70% 1.4 a 50s2 30% 4.1 a 50s2 γ 0.27 a 39S10	
Level 0.5 Ge^{77}		
Fission chem 50s2, 48SP d 59^{s}Ge 47A1 d 12^{h}Ge 49M28, 48M32, 50s2 Not p 17.5^{s}Se 49F10	Fission chem 50s2 Br-n-α chem 39S10 Se-n-p chem 39S10 d 2.1^{h}Ge 50s2	

80 33 47	81 33 48	
	τ $<10^m$ 49G15 Fission	No As found in fission with $\tau > 3^d$ 50w2, 50l1

Neutron Cross Sections for Natural Element	69 34 35	70 34 36
$E_n = 0.025$ev σ_a 12.1 49P3 12.5 49H2 σ_s 13 37G1 σ_t 21 37G1 Values at other energies 49H16 $E_n \sim 3$Mev σ_t 4.0 39Z1 Other fast n values 48WH		τ 44^m 48H4 β^+ 48H4 As-d chem 48H4 p 52^m As which has no active Ge daughter 49H14

71 34 37	72 34 38	73 34 39
	τ 9.7^d 49H14 K 48H4 As-d-5n chem 48H4 p 26^hAs 48H4	τ 6.7^h 48H4 7.1 48C7 K ~50% 48C7 β^+ ~50% 1.29 a 48C7 γ ? 48C7 Ge-α-n chem 48C7 As-d-4n chem 48H4 Not produced by As-d-2n 48C7

74
34 40

	0.96%		49H3
	0.87		48W9
I	0 ?	Mic	49S7
Level	0.582 ?		As^{74}
	σ's		
(th n,γ) 127^{d}Se	22		47F8,47S33
	26		50g20

75
34 41

τ

127^{d}	48C7
120	48H4
125	50g20
115	47F8

K 47F8,50g20

No β^{+} 47F8

γ

49T2	48J13,48J6
	0.067
0.076	0.077
0.099 ?	0.099
0.123	0.124
0.137	0.139
	0.203
0.267	0.269
0.283	0.281
	0.308
0.405	0.405

Note: 0.123 and 0.283 = 0.406
0.137 and 0.267 = 0.404

No delayed $\beta\gamma$ coincidences 49M26

As K´X-ray 47F8,50g20

Ge-α-n	chem	48C7
As-p-n		44D9
As-d-2n	chem	48C7,42K5
Se-n-γ	chem,σ	47F8,50g20

d 1.7^{d}Br ? 125^{d} activity found after Se^{74}-p 48W8

76
34 42

	9.12%		49H3
	9.02		48W9
I	0 ?	Mic	49S7
Levels	0.567		As^{76}
	1.8		As^{76},Br^{76}?
	2.7		As^{76}
	others ?		Br^{76}
	σ's		
(th n,γ) 17.5^{s}Se	~7		47A1

77
34 43

τ 17.5^{s} 49G4,47A1

IT 48G17

γ

~0.15	a	47A1
0.15	ac	49G4

Se K X-ray 48G17

Se-n-γ σ 47A1
Se^{76}-n-γ 48G2,47D10
Se-γ 49G4

Not d 40^{h}As 49F10

	7.50%		49H3
	7.58		48W9
I	1/2 ?	Mic	49S7
	>1/2	S	49M11
Levels	0.7		Br^{77}
	1.45		49G4
	from γ excitation curve		

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78
34 44

	23.61%		49H3
	23.52		48W9
I	0 ?	Mic	49S7
Levels	0.046 } ?		Br^{78}
	0.108 } ?		
	0.27 ?		As^{78}

79
34 45

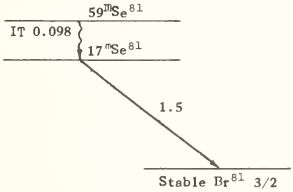
τ	6.5×10^4 y		49P14
	$>7 \times 10^6$		
	if β energy >30kev		50g1

80
34 46

	49.96%		49H3
	49.82		48W9
I	0	B	3401
Levels	?		Br^{80}
	σ's		
(th n,γ)17^mSe		0.46	47S33
		0.50	47A1
(th n,γ)59^mSe		0.034	47S33

81
34 47

τ_1	59^m		50g1
	57		37S2,40L3
	56.5		48W13
τ_2	17^m		50g1
	19		40L3
	13.6		48W13
$59^m Se^{81}$			
IT	0.098	sc,a	40L3
	0.099	sc	41H1
	K/L = 4		41H1
$17^m Se^{81}$			
β^-	1.5	a	40L3,46PP
No γ			46PP



Fission	chem		50g1
Se-d-p	chem		37S2,40L3
Se-n-γ	σ		47A1,47S33
Se^{80}-n-γ			47L14
Se-γ-n	relσ		48W13
Br-n-p	chem		37S2,40L3
p $17^m Se^{81}$	chem		40L3,50g1
Fission	chem		50g1
Se-d-p	chem		37S2,40L3
Se-n-γ	σ		47A1,47S33
Se-γ-n	relσ		48W13
threshold = 9.8			45B12
Br-n-p	chem		40L3
d $59^m Se$	chem		40L3,50g1

82
34 48

	8.84%		49H3
	9.19		48W9
I	0 ?	Mic	49S7
Levels	?		Br^{82}
	σ's		
(th n,γ)67^sSe		0.047	47A1
(th n,γ)25^mSe		0.004	47A1

83 34 49								84 34 50		
τ_1	67^s		47A1	τ_2	25^m		50k1	τ	$\sim 2^m$	50e1,50k2
					30		40L3			
β^-	3.4	a	47A1	β^-	1.5	a	46PP			
γ			47A1	γ	0.17	a	46PP			
					0.37	a				
					1.1	a				
				Fission			48SP			
Fission			50g2		chem		46PP	Fission	chem	50e1,50k2
Se-n-γ	chem,σ		47A1	Se-d-p	chem		40L3			
				Se-n-γ	chem,σ		47A1			
					chem		40L3			
	p 2.4^{h}Br		47A1		p 2.4^{h}Br		50k1		p 30^{m}Br	50e1,50k2

No long lived Se other than Se^{79} produced in fission 50w3, 50g1

Neutron Cross Sections of Natural Element			
σ_s coh	5.7		49S12
	$E_n = 0.025$ev		
σ_a	6.4		49P3
	9.1		49H2
σ_s	7		37G1
	Resonance		
E_o	<115ev		49H16
	$E_n = 2.5$Mev		
σ_t	2.7		39A5

75 35 40			
τ	1.7^h		48W8
K ~81%			48W8
β^+ ~19%	1.6	a	48W8
No γ			48W8
Se^{74}-d-n			48W8
Se^{74}-p-γ			48W8
p 127^dSe ?			
125^d activity found after Se^{74}-p			48W8

76 35 41			
τ	15.7^h		48H27
β^+	3.15	s	48H27
γ	2	a	48H27
e^-	0.18	s	48H27
As-α-3n	chem		48H27

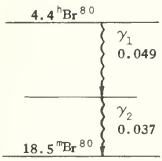
77 35 42			
τ	57.2^h		48H27
	58		48W8
K 95%			48W8
β^+ 5%	0.36	a,s	48W8
	0.36	s	48H27
γ	0.7		48H27
Se^{74}-α-p			48W8
Se^{76}-d-n			48W8
As-α-2n	chem		48H27

78 35 43			
τ	6.4^m		37S2
	6.3		48W13
β^+	2.3	a	37S2
γ	0.046	sc	39V2
	0.108	sc	39V2
As-α-n	chem		37S2
Se-d-n	chem		37S2
Se-p-n	chem		38B4
Br-γ-n	relσ		39B5,48W13
threshold = 10.7			49M17
Br-n-2n			37S2
threshold = 9-13			38S14

79 35 44			
	50.57%		49H3
	50.51		48W9
	50.5		46W3
I	3/2	S	32T2,40T2
		Mic	47T16
μ	2.0999		49Po
		I	49Z2,47P16
		M	47B24
q	+0.28		47T15
Level	0.2		Kr^{79}
	σ's		
(th n,γ)4.4^hBr	8.9		49H5
	8.1		47S33
(th n,γ)18^mBr	3.0		49H5
	2.8		47S33
(~1Mev n,γ)4.4^hBr	0.014		49H5
(~1Mev n,γ)18^mBr	0.030		49H5
Other fast n values			48WH

$^{80}_{35}45$

τ_1	4.4^h		38B4
	4.5		37S2



Se^{80}-p-n	chem		48W8
threshold	~3.1		38B4
Se-d-2n			48W8
Se-α-p			48W8
Br-d-p	chem		37S2
Br-γ-n	relσ		48W13,39B5
Br-n-2n			37P2
Br-n-γ	chem		37S2
	σ		49H5,47S33

γ_1	0.049	sc	39V2
	α=∞		40G6
	chemical effects		
	α=∞		49H15
	chemical effects		
	α=57		40D3
	assuming α=∞,K/L=7.3		44B7
	0.047	cc	41S4
	α=1	K/L=10	41S4
	(assuming no conversion of other γ)		
γ_2	0.037	sc	39V2
	α=0.64	K/L=6.8	44B7
	0.037	a	40G6
	α=1		40G6
	0.037	cc	41S4
	α~2		40D3
Relative amounts of isomers produced by different reactions			39B5

τ_2	18.5^m		37S2
β^-	2.0	a	48C25
complex	2.3	a	37S2(46B27)
	2.0	s	36A1
β^+ 3%	~0.7	a	47B8
	~0.8	s	48W8
1.0%	1.0	s	49D19
β^- and β^+ ft values		~ equal	49D19
γ	>0.6	a	40D3
	<0.5	a	37S2
Se-p-n	chem		38B4
threshold	~ 2.9		38B4
Br-d-p	chem		37S2
Br-γ-n	relσ		48W13,39B5
threshold	= 10.2		49M17
Br-n-2n			38S13,37P2
Br-n-γ	relσ,chem		49F15
	chem		37S2
	σ		49H5,47S33
d 4.4^hBr			39S3,40D3,41S4

$^{81}_{35}46$

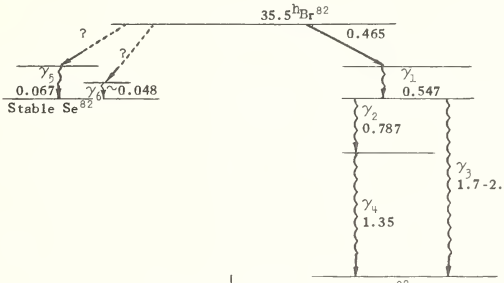
	49.43%		49H3
	49.49		48W9
	49.5		46W3
I	3/2	S	32T2,40T2
		Mic	47T16
μ	2.2633		49Po
		I	49Z2,49B7, 47P16
		M	47B24
q	+0.23		47T15

σ's

(th n,γ)36^hBr	2.3	47S33
(~1Mev n,γ)36^hBr	0.017	49H5
Other fast n values		48WH

$^{82}_{35}$ ^{47}

τ	35.5^h		49T5
	33.9		37S2
	36		35K1



Se-p-n	chem		38B4,41R2
Se-d-2n	chem		37S2
Br-n-γ	chem		37S2
	σ		47S33
Br-d-p	chem		37S2
threshold	~3		44C1
Rb-n-α	chem		37S2
Fission	chem		50f1,48SP,49G13

γ_1, γ_2, γ_4 in cascade 41R1
High energy e^-'s probably secondaries 42D4
No β^+ 49D19
β^+/β^- $\leqslant 0.004$ through 30 mg/cm^2 Al 47B5

K	<5%	No X-ray found		41R1
β^-		0.465	s	41R1
γ_1		0.547	s	41R1
γ_2		0.787	s	41R1
γ_3	0.14%	1.7-2.0	γn	49M8
γ_4		1.35	s	41R1
γ_5		0.067*	ac	44B7
γ_6		~0.048*	ac	44B7

γ's photo	conv.	rel. int.	49S30
0.553	0.547	0.68	
0.613	0.608	0.78	
0.685	0.692	0.42	
0.772	0.766	1.00	
0.826	0.823	0.13	
1.045	1.031	0.18	
1.317	1.312	0.14	

*Assuming K conversion. No e^-e^- or βe^- coincidences observed 44B7

$^{83}_{35}$ ^{48}

τ	2.4^h		50k1
	2.3		40L3
β^- complex	1.45	a	37S2(46B27)
	0.9	a	46PP
	1.1	a	40L3
	1.0		50k1
No γ			37S2,46PP

Levels Se^{83}

0.17, 0.37, 1.1 ?

Se-d-n	chem		37S2
Fission	chem		40S3,48SP, 49G13,50k1
	d	25^mSe	50e1,40L3
	p	1.88^hKr	50e1,40L3

$^{84}_{35}$ ^{49}

τ	33^m		50k2
	30		40S3
β^-	5.3	a	50k2
	4.5	a	43B2
γ			50k2

Rb-n-α			43B1
Fission	chem		39D2,48SP
	d	~2^mSe	39D2,50e1

$^{85}_{35}$ ^{50}

τ	3.00^m		49S14
	3.0		40S3,43B1
β^-	2.5	a	49S14
No γ			48S16

Fission	chem		48S16,43B1,48SP
	p	4.5^hKr	40S3,43B1

86 35 51	87 35 52	88 35 53
	τ 55.6^{s} 48H33 55.0 47R2 56.1 49S14 β^- 40S3 55% ~2 a 49S15 45% ~8 a 49S15 Delayed neutron emitter 47S7 $\overline{E_n}$ 0.25 48H33 0.3 46B22 γ >3 a 49S15 Delayed n's in ~2% of disintegrations 50l2 Fission chem 40H12,48SP p 78^{m}Kr 43B1,43S1	τ 15.5^{s} 49S14 β^- 49S14 Fission chem 49S14 p 3^{h}Kr 49S14
89 35 54		
τ 4.51^{s} 47S10,46PP 4.3 46S28 β^- 46PP,47S10 Delayed neutron emitter 47S10 $\overline{E_n}$ 0.43 a 46PP Fission chem 47S10 Mass 87-90 from fission fragment range 47S10	No Br with τ >3^{d} found in fission 50k1	

Neutron Cross Sections for Natural Element			77 36 41			78 36 42	
	E_n = 0.025ev		τ	1.1^h	48W7	0.342%	47L2
σ_a	0.045	44W11				0.36%	47D9
σ_t	24	42R3					
			K ~70%		48W7		
σ_s	6.7	50H5	β^+~30%	1.7 a	48W7		
			γ		48W7		
						σ's (th n,γ) 34^hKr	0.26 50h2
			Se^{74}-α-n	chem	48W7		

79 or 81 36			79 36 43			80 36 44	
τ	13^s	40C6	τ	34.5^h	40C6	2.228%	47L2
				34	48W7	2.25	47D9
γ	0.187 sc	40C6	K 98%		48W7		
			β^+ 2%	1.0 a	48W7		
				~0.6 a 70%	50h2		
				~0.9 a 30%	50h2		
			γ	0.2 a	50h2		
						Level ~0.5	Br^{80}
			Kr-d-p	chem	41C2		
			Se^{76}-α-n	chem	48W7		
Br-p-n		40C6	Br-d-2n	chem, f	44C1		
				yield	46C9, 44C1		
			threshold = 5.3		46C9, 44C1		
			Kr-n-γ	chem, σ	50h2		
			Br-p-n	chem	40C6		

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

81 or 79			81			82		
36			36 45			36 46		
τ	55^{s}	40C6					11.50%	47L2
							11.57%	47D9
γ	0.127 sc	40C6						
			Level	0.8	Rb^{81}	Levels	?	Br^{82}, Rb^{82}
Br-p-n		40C6						
Se-α-n ?		39K1						

83						84		
36 47						36 48		
τ	1.88^{h}	40L3		11.48%	47L2		57.02%	47L2
	1.9	46R7		11.44	47D9		57.14	47D9
γ	0.029 sc	41H1	I	9/2 S	49K21, 38K2			
	0.046 sc	41H1	μ	-0.968 M	46K5			
	K/L = 1	41H1	q	+0.15 S	49K21, 38S10			
							σ's	
						(th n,γ) 4.4^{h}Kr	0.096	50h2
Se-α-n	chem	41C2				(th n,γ) 10^{y}Kr	0.063	50h2
Kr-d	chem	41C2				(~1Mev n,γ) 4.4^{h}Kr	1.9mb	49H28
Kr-γ-γ		45W3				(~1Mev n,γ) 10^{y}Kr	<8mb	49H28
Kr-n-γ		45W3						
Kr-n-n		46R7						
Fission	chem	46PP						
	d 2.4^{h}Br	40L3						

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

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85
36 49

τ	4.36^{h}		49K13
	4.5		50h2,37S2
	4.4		48W7
	4.6		46R7
β^-	1.0	a	50h2
	0.75	a	49K13
	0.85	a	43B2
γ	0.17	a	50h2
	0.37	a	50h2
Fission	ms		49K13
	chem		50h2
Se-α-n	chem		48W7
Kr-d-p	chem		41C2
Kr-n-γ	σ		50h2
Rb-n-p	chem		43B1
Sr-n-α	chem		43B1
	d 3^{m}Br		43B1,43S1

τ	$\sim 10^{y}$		47T6,50h1
β^-	0.74	a	50h1
No γ			50h1
Fission	ms		47T6
	chem		50h1
Kr-n-γ	σ		50h2

86
36 50

	17.43%	47L2
	17.24	47D9
σ's		
(th n,γ)78^{m}Kr	0.061	50h2
($\sim$1Mev n,γ)78^{m}Kr	2.4mb	49H28

87
36 51

τ	78^{m}		49K13
	74		37S2
	75		43S1
β^-	3.2	a	49K13
	$\sim$4	a	43B2
Neutrons emitted following 56^{s}Br disintegration			Br^{87}
σ's			
(th n,γ)	<470		50h2,45S17
Fission	ms		49K13
	chem		43B1,43S1
Kr-d-p	chem		37S2
Rb-n-p	chem		43B1
Kr-n-γ	σ		50h2
	d 56^{s}Br		43B1,43S1

88
36 52

τ	2.77^{h}		49K13
	3		40H4,39L11
	2.8		40G5
β^-	$\sim$0.5	a	49K13
	2.4 ?	a	49K13
	2.4	a	48J20
	2.5	cc KU	42W1
γ			49K13
Distribution of nuclear recoils indicates β's and neutrinos emitted in same direction			46J3
Fission	ms		49K13
	chem		40S5,40H10
	p 17.8^{m}Rb		40G5,40H10

89
36 53

τ	2.6^{m}		50d1
	2.5		43H9
Neutrons emitted following 4.5^{s}Br disintegration			Br^{89}
Fission	chem		50d1,40S5,40H10
	p 15.4^{m}Rb		40G5,40H10
	p 53^{d}Sr		40G5,50d1

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

90 36 54	91 36 55	92 36 56
τ 25^{s} 50d1 33 46PP	τ 9.8^{s} 50d1 5.7 50o1	τ 2.4^{s} 50d1
		Mass assignment from range of fission fragments 48K9
Fission chem 50d2	Fission chem 48SP, 50d1	Fission chem 43H9, 50b2, 50d1
p 25^{y}Sr 50d2, 46PP	p 9.7^{h}Sr 50d1 p 57^{d}Y 50b2, 50d2, 50o1	p 3.5^{h}Y 50b2, 50d1, 40H10

93 36 57	94 36 58	97 36 61
τ 2.3^{s} 50d1	τ 1.4^{s} 50d1	τ $\sim 1\text{-}2^{s}$ 50d1
Fission chem 43H9, 50d1, 50d2, 50b2	Fission chem 43H9, 50d1	Fission chem 50d1
p 10^{h}Y 50d1, 50d2, 50b2, 46S18	p 16.5^{m}Y 43H9, 50d1	p 17^{h}Zr 50d1 contested by 50g2

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

Neutron Cross Sections for Natural Element				80 37 43				81 37 44			
σ_s	coh	3.8	49S12					τ	5.0^h		49R1
σ_s	bound	5.5	49S12								
		$E_n = 0.025$ev						K ~70%			49R1
σ_a		0.70	49P3					β^+ ~30%	0.9	a	49R1
σ_t		12	42L1					γ	0.8	a	49R1
								e^-	0.2	s	49R1
								K X-ray			49R1
								Br-α-2n	ms, chem		49R1
								Br-α-4n	chem		49R1
								Kr daughter not observed			49R1

82 37 45				82 ? 37 45 ?				83 37 46
τ_1	6.3^h		49R1	τ_2	20^m		40H11	
	6.5		40H11					
K ~85%			49R1					
β^+ ~15%	0.9	a	49R1					
γ	1.0	a	49R1					
X-ray			49R1					
Note γ's of Br^{82}								
Br-α-n	ms, chem		49R1	Br-α-n	chem		40H11	
Br-α-3n	chem		49R1		Not produced by			
Kr-d-2n	chem		40H11	Kr-d			40H11	

84
37 47

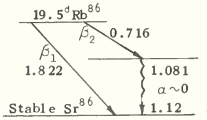
τ	$\sim 40^{d}$	47B8
β^{+}		47B8
K		49G13
K X-ray		49G13
Br-n-2n		47B8
Sr-d-α		47B8

85
37 48

	72.8%		36N5
I	5/2	S	33J1, 33K1
		Z	36M1
		M	40M11
μ	1.349		49Po
		I	49B7, 49C2
		M	39K7
Levels ?	0.17		Sr^{85}, Kr^{85}
	0.37		Kr^{85}
	0.510		Sr^{85}
	σ's		
(th n,γ) 19.5^{d}Rb	0.7		47S33
($\sim$1Mev n,γ) 19.5^{d}Rb	0.023		49H28

86
37 49

τ	19.5^{d}		48W13, 41H2
	18		37S2



β_1^- 80%	1.822	s	48Z2
87%	1.8	a	48J7
	1.8	a	50f2
	1.60	s	42H1
β_2^- 20%	0.716	s	48Z2
33%	0.56	a	48J7
$\beta\gamma$ angular correlation indicates I (Rb^{86}) = 2			49F16
Rb-n-γ	chem		37S2, 38S6
	σ		47S33
Rb-γ-n			44H5
	relσ		48W13
Sr-d-α	chem		41H2
Fission	chem		50f2

87
37 50

	27.2%		36N5
I	3/2	S	33J1, 33K1
		Z	36M1
		M	40M11
μ	2.742		49Po
		I	49B7, 49Z2
		M	39K7
	σ's		
(th n,γ) 17.8^{m}Rb	0.12		47S33
($\sim$1Mev n,γ) 17.8^{m}Rb	1.8mb		49H28

τ	6.0×10^{10} y		49K28, 48H41
	6.3×10^{10}		38S8
	5.8×10^{10}		46E2
β^- or e^-	0.13	s	41G3, 39L1
	0.25		35K4
	0.144	s	46S1
	0.56	cc	48F10
	<0.01	a	48H41
γ	0.034	sc	? 41G3
	0.053	sc	
	0.082	sc	
	0.102	sc	
	0.129	sc	
βe^- coincidences			48H41

88
37 51

τ	17.8^{m}		40G5
	17.5		42W1
	18		39H4
β^-	5.0	a	40G5 (46B27)
	5.1	cc	42W1
	2.5	cc	42W1
γ			49K13
	σ's		
(th n,γ)	<200		45S17
Rb-n-γ	chem		37P2, 37S2
	σ		47S33
Fission	chem		39H3, 40G5, 42W1, 40H10
	d 3^{h}Kr		39L11, 40H10

89 37 52				90 37 53				91 37 54			
τ	15.4^{m}		40G5	τ	short		50d2	τ	short		40H9,50d1
	15.5		40H10								
β^-	4.5	a	40G5(46B27)								
Fission	chem		43H4	Fission	chem		50d2	Fission	chem		50d1
	d 2.6^{m}Kr		43H4		d 25^{s}Kr		50d2		d 9.8^{s}Kr		50d1
	p 53^{d}Sr		40G5		p 25^{y}Sr		50d2		p 57^{d}Y		50d1

92 37 55			93 37 56			94 37 57		
τ	short	50b2,50d1	τ	short	50d1,50d2,50b2	τ	short	50d1,43H9
Fission	chem	50b2,50d1	Fission	chem	50d1,50d2,50b2	Fission	chem	50d1,43H9
	d 2.4^{s}Kr	50b2,50d1		d 2.3^{s}Kr	50d1,50d2,50b2		d 1.4^{s}Kr	50d1,43H9
	p 3.5^{h}Y	50b2,50d1		p 10^{h}Y	50d1,50d2,50b2		p 16.5^{m}Y	50d1,43H9

95 37 58	96 37 59	97 37 60
		τ short 50d1 Fission chem 50d1 d 1-2^{s}Kr 50d1 p 17^{h}Zr 50d1 See also 50g2
>90 37		
τ 80^{s} 40H4 Fission chem 40H4		

Neutron Cross Sections for Natural Element											
σ_s	coh	4.1		49S12							
σ_s	bound	9.5		49S12							
		$E_n = 0.025$ev									
σ_a		1.2		49P3							
		1.5		49H2							
σ_s		9.5		37G1							

84 38 46	
0.56%	38N3
0.55	48W9

85 38 47											
τ_1	70^m		40D5	τ	65^d		40D1				
γ	~0.17	sc	40D5	K			40D1				
				No β^+			49T14				
				γ	0.510	sc	49T14				
					0.8	a	40D5				
				Auger e's from Rb L and M shells			49T14	Level	1.08		Rb^{86}
								σ's			
								(th n,γ) 2.7^hSr	1.3		47S33
								assuming 15% internal conv.			
Rb-p-n	chem		40D5	Rb-p-n	chem		40D5				
				Rb-d-2n	chem		49T14, 42O3				

86 38 48	
9.86%	38N3
9.75	48W9

87
38 49

τ	2.75^h		40D5
γ	0.37	sc	40D5
	0.386	sc	41H1
	α = .18, K/L ~7		41H1
Sr K X-ray			40D5
Sr-d-p	chem		40D5
Sr-n-γ			47S11
Sr^{87}-n-n	σ		40R4
Zr-n-α	chem		40S8
Sr-e^--e^-			45W2
Sr-X			45W2
Sr-p-p(?)			40D5
Rb-p-n	chem		40D5
d 80^hY			40D5

	7.02%		38N3
	6.96		48W9
I	9/2	S	38H5
μ	-1.1	S	38H5
Levels	0.37		$2.75^h Sr^{87}$
	others ?		Rb^{87}
	σ's		
(~2.5Mev n,n) 2.7^hSr	0.3		40R4

88
38 50

	82.56%		38N3
	82.74		48W9
I	0	S	38H5
Levels	1.85		Y^{88}
	2.76		
	σ's		
(th n,γ) 53^dSr	5mb		47S33
(~1Mev n,γ) 53^dSr	2.1mb		49H28

89
38 51

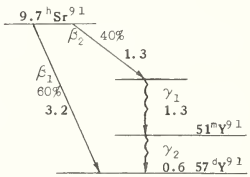
τ	53^d		50n3
	55		39S8
	54.5		46G6
β^-	1.50	s	49S10
	1.463	s	49L6
	1.5	s	50n3, 47R1
β spectrum shape consistent with ΔI = 2, yes			49L6, 49S10
No γ			49S10, 39S8, 50n3
	σ's		
(th n,γ)	<110		45S17
Fission	ms		48H25
Sr-n-γ	chem		39S8
Sr-d-p	chem		39S8
Zr-n-α ?	chem		40S8
Y-n-p			38S3
Fission	chem		49G13, 50n3
d 15^mRb			40G5, 46G6, 40H10

90
38 52

τ	25^y		50g3
	23		50n4
β^-	0.537	s	49J1
	0.531	s	49B11
	0.61	s	48M8
	0.6	a	50g3
β spectrum shape consistent with ΔI = 2, yes			49B11, 49J1
No γ			50g3, 46PP
	σ's		
(pile n,γ) 9.7^hSr	~1		49S11
Fission	ms		48H25
	chem		46PP, 48SP, 49G13
d 25^sKr			46PP
p 61^hY			50n4, 46PP

91
38 53

τ	9.7^h		50f3
	10		43H4



β_1^- 60%	3.2	a	50f3
β_2^- 40%	1.3	a	50f3
γ_1	~1.3	a	50f3
γ_2	0.6	a α~0.1	50f3
Zr-n-α	chem		43S3
Fission	chem		40H4, 46PP, 48SP, 49G13
d 9.8^sKr			46PP
p 60% 57^dY			50f3
40% 51^mY			50f3

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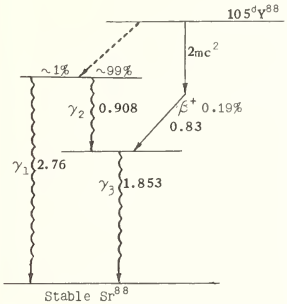
92 38 54	93 38 55	94 38 56
τ 2.7^{h} 41G4	τ 7^{m} 39L10	τ $\sim 2^{m}$ 43H4
β^{-} 41G4	β^{-} 39L10	
Fission chem 41G4, 43H9, 50b2	Fission chem 39L10, 43H9	Fission chem 43H4, 50d1
d 2.4^{s}Kr 50b2, 40H4 p 3.5^{h}Y 50k5, 41G4, 43H9	d 2.3^{s}Kr 42H8, 39L10 p 10^{h}Y 43H9	d 1.4^{s}Kr 43H9 p 16.5^{m}Y 43H9

95 38 57	96 38 58	97 38 59
		τ short 50d1
		Fission chem 50d1
		d 1-2^{s}Kr 50d1
		see also 50g2

Neutron Cross Sections for Natural Element		
	E_n = 0.025ev	
σ_a	1.38	49P3
σ_s	<14	37G1
σ_t	~4	42B4

84 39 45			87 39 48					
τ	3.7^h	49S9	τ_1	14^h	40D5	τ_2	80^h	40D5
K		49S9	IT ?		40D5	K		50R3, 40D5
β^+	2.0 a	49S9	K		50R3	β^+	0.7	50R3
γ		49S9	β^+	1.1	50R3	γ	0.5 sc, a	50R3
Sr X-ray		49S9				Sr K_α X-ray		50R3
Sr^{84}-d-2n	chem	49S9	Sr-p-n	chem	40D5	Sr-p-n	chem	40D5
Sr^{84}-p-n		49S9	Sr-d-n	chem	40D5	Sr-d-n	chem	40D5
						Rb-α-n		48R9
Not produced by								
Sr^{86}-d		49S9						
Sr^{87}-d		49S9					p 2.7^hSr	40D5

88
39 49



τ_1	105^d		49S9, 40D5
	104		4702
β^+ 0.19%	0.83		48P13
γ_1 ~1%			43G4
	2.76	s	48P13
γ_2 ~99%			43G4
	0.908	s	48P13
	$\alpha = 2.7 \times 10^{-4}$		48P13
	0.9		4605
	0.95		41R3
γ_3	1.853	s	48P13
	$\alpha = 1.3 \times 10^{-4}$		48P13
	1.89	s	41D4
	1.92	cc	41R3
	1.87	γn	41S5
	1.9		4605
$\gamma\gamma$ angular correlation consistent with I = 2, 1, 0			48B18
τ_2	2.0^h		39S8
β^+	1.65	a	4605
	1.2	cc	37S3
Sr-p-n	chem		40D5
Y-n-2n	chem		4605
Sr-d-n	chem		39S8
Not produced by Y-fast n's, Sr-d, Rb-α			49S9
Y-n-2n	ms		48H25
	chem		42H2, 4605
Sr-p-n	chem		40D5
Sr-d-2n	chem		40P1, 43G4
threshold = 6, yield			46C9

89
39 50

	100%		39D5
I	1/2	S	49C17
μ	-0.14	S	49C17
σ's			
(th n, γ) 61^hY	1.24		47S33
(th n, γ)	1.38		49P3
(~1Mev n, γ) 61^hY	7mb		49H28

90
39 51

τ	61^h		46B25
	65		50n4
β^-	2.180	s	49L6
	2.25	s	49B11
	2.23	s	49J1
	2.35	s	48M8
β spectrum shape consistent with ΔI = 2, yes			49J1, 49L6, 49B11
No γ			49B11, 50g3
Y-d-p	chem		37S3
Y-n-γ	chem		37S3, 38S3
	σ		47S33
Zr-n-p			40S8
Zr-d-α			38S3
Nb-n-α			38S4
Fission	chem		50n4, 50g3, 49G13
d 25^ySr	ms		48H25

91
39 52

τ_1	51^m		50f3
	50		41G4
IT			50f3
γ	0.61	a	50f3
	$\alpha \sim 0.1$		50f3

See decay scheme of Sr^{91}

51^mY produced by

Zr-n-p	chem	43S3
Fission	chem	50f3, 41G4, 43H4
40% d	$9.7^h Sr$	50f3
p	$57^d Y$	50f3

τ_2	57^d		44J4, 40H9
	61		46G6
β^-	1.537	s	49L6
	1.54	s	49O3
	1.55	s	49W17

β spectrum shape consistent with $\Delta I = 2$, yes 49L6, 49O3, 49W17

γ very weak	0.2	a	49L6
very weak	1.22	a	49L6

γ's in cascade 49L6

No γ 50b4

57^dY produced by

Zr-n-p	chem	43S3
Fission	ms	48H25
	chem	49G13, 50f3, 41G4
60% d	$9.7^h Sr$	50f3, 41G4, 43S3

92
39 53

τ	3.5^h		43H9, 39L10
β^-	3.5	a	50h3
	3.6	a	43B2
	3.4	a	41G4
γ	0.7-1.1	a	46PP
	0.6	a	41G4

Mass assignment from range of fission fragment 48K9

Fission	chem	50h3, 48SP, 49B10
Zr-n-p	chem	43S3
d	$2.7^h Sr$	43H4, 50h3

93
39 54

τ	10.0^h		50b6
	11.5		39H10
β^-	3.1	a	50b6
γ	0.7	a	50b6

Mass assignment from range of fission fragment 48K9

Fission	chem	50b6, 49G13
d	$7^m Sr$	43H4
Not p	$65^d Zr$	50s15
	See Zr^{93}	

94
39 55

τ	16.5^m		49B10
	20		43H4
β^-	5.4	a	49B10
γ	1.4	a	49B10

Mass assignment from range of fission fragment 48K9

Zr-n-p	chem	43S3
Fission	chem	50d3
d	$2^m Sr$	43H9

95
39 56

τ	$<1.5^h$		50s15

96 39 57	97 39 58	
	τ short 50d1	
	Fission chem 50d1 d 1-2^{s}Kr 50d1 p 17^{h}Zr 50d1 See also 50g2	

Neutron Cross Sections for Natural Element			87 40 47			
σ_s coh	4.9	49S12	τ	2.0^h		49S9
σ_s bound	7-8	49S12				
	$E_n = 0.025$ev		K			49S9
σ_a	0.22	49P3				
	0.4	49H2	β^+	2.0	a	49S9
σ_s	8.2	(48WH)	γ	0.35	a	49S9
				0.65	a	49S9
			X-ray			49S9
Resonances found by 47H25 probably due to Hf impurity		49B2				
Graphs Available						
σ_t	0.025-100ev	47H25,47GIF	Sr^{84}-α-n			49S9
	0.020-1.60Mev	49B28,50Ad				

89 40 49						90 40 50	
τ_1	4.5^m	40D5	τ_2	80.1^h	4301	51.46%	48W9
				78	40D5	51.7	49H39
K or IT		48H36	β^+	1.07 a	4301		
				~1 a	40D5		
e^-	0.555 s	48H36	No γ		40D5		
						Levels	Nb^{90}
						~0.04, 0.25, 1.66, 2.03 ?	
						σ's	
						(th n,γ) 0.11	49P3
Y-p-n	chem	40D5	Zr^{90}-γ-n		49B3	Zr^{91}-γ-n	49H17
Zr-n-2n		48H36	threshold = 11.9		49B3	threshold = 7.2	49H17
Zr^{90}-γ-n		49B3,49H17	Zr-n-2n	chem	40S8	(only n's observed)	
threshold = 12.48		49H17	Y-d-2n		4301		
threshold = 12.1		49B3	Y-p-n	chem	40D5		
			Mo-n-α	chem	40S8		

91
40 51

	11.23%		48W9
	10.8		49H39
I	5/2	S	49A6
	σ's		
(th n,γ)		1.52	49P3

92
40 53

	17.11%		48W9
	17.1		49H39
Level	~0.7		Y^{92}
	σ's		
(th n,γ)		0.25	49P3

93
40 53

τ	>4x10^{6y}*		49B44
	very long *		49C20
	>40 **		48L4
	>100 **		50S15
Level	~0.7		Y^{93}

* From fission yield
** From decay of 10^{h}Y

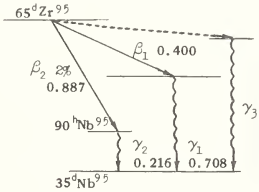
94
40 54

	17.40%		48W9
	17.5		49H39
Level	1.4		Y^{94}
	σ's		
(th n,γ)		0.08	49P3
(th n,γ)65^{d}Zr		0.06	49L16
		0.43	47S33

95
40 55

τ	65^{d}	50b1,43H9,46G6	
	65.5		45P1
	63		40S8

Tentative decay scheme 50l3



Fission	ms		46PP
	chem	49G13,46PP,48SP, 43H8,40G4,46G6	
Zr-n-γ	chem		40S8
	p (1.4%) 90^{h}Nb		49H31
	p (98.6%) 35^{d}Nb		49H31
	p 90^{h}Nb		50S3
	p 35^{d}Nb	46G6,50e2,50b1	

β_1	0.400	s	49L17
	0.39	s	50n1
	0.42	a	50b1
	0.4	a	48M14
β_2 2%	0.887	s	49L17
2%	1.0	s	50n1
5%	1.0	a	50b1
γ_1	0.708	sc	49L17
	0.73	sc	50n1
γ_2	0.216	sc	49H31
	α=∞		49H31
	0.24	sc	50l3
	0.23	sc	50n1
γ_3 ? weak	0.92	s	50n1
	0.8	a	50b1
	0.91	a coin	48M14
This line belongs to 35^{d}Nb daughter (?)			48M1
Zr-n-γ	σ		47S33
Zr-d-p	chem		50j1,40S8
Zr-n-2n	chem		40S8
Mo-n-γ	chem		40S8

96 40 56	97 40 57	?
2.8% 48W9 2.9 49H39	τ 17.0^{h} 40G4,50k3,40S8	τ 6^{m} 47S33,40S8
	β^- 2.2 a 50k3 1.1 cc 40S8	
	γ ~0.8 a 50k3	
σ's (th n,γ) 0.10 49P3 (th n,γ)17^{h}Zr 0.045 49L16 0.60 47S33 (pile n,γ)17^{h}Zr 0.2 49L16	Fission chem 40G6,40H9,41A3 Zr-n-γ chem 40S8,49P16 σ 47S33 Mo-n-α chem 40S8 Not produced by Nb-n-p 50j1 d 1-2^{s}Kr 50d1 contested by 50g2 p 76^{m}Nb 40G4,41H5,50b3	Zr-n-γ 47S33,40S8 σ(atomic) = 0.016 47S33
No Zr$^{>97}$ found in fission with τ between 2^{m} and 100^{y} 49C20 No Zr with τ <5^{m} found by nγ on separated Zr isotopes 49B42		

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Neutron Cross Sections for Natural Element		
σ_s coh	6.0	49S12
σ_s bound	6.2	49S12
	$E_n = 0.025$ev	
σ_a	1.06	49P3
	1.48	49H2
σ_s	5	37G1
σ_t	6.4	47W8
Graphs Available		
σ_t	0.008-1000ev 50Ad,47GIF,47W8	

90
41 49

τ	15^h		49K19,49B29
	17-18		50J1
β^+	~1.7	a	49B29
	1.9		49K19
γ	~0.04	a	49B29
	0.25	a	49B29
	1.66	a	49B29
	2.03		49K19
Zr-d-2n			50J1
Mo-d-α			50J1
Mo^{92}-d-α	chem		49K19,49B29
Zr^{90}-d-2n			49K19
Not produced by			
Zr^{91}-d			49K19

91
41 50

τ	64^d		49B29
	60		50J1
IT ?			49B29
e^-			49B29
Nb X-ray			49B29
γ	~0.05		49B29
Mo^{94}-d-αn	chem		49B29
Zr-d-n	chem		50J1

92
41 51

τ	10.1^d		47K1
	9.8		48M33
	11		40S6
β^-	1.38		47K1
	1.38	cc	40S6
γ	1.1		45P1
	1.0		47K1
Zr K X-ray			47K1
Nb-γ-n			48M33
Zr^{92}-d-2n			49K18
Mo^{94}-d-α	chem		49B29
Y-α-n			45P1
Nb-d-t			47K1,46W2
Nb-n-2n			40S6
Not found from Nb-n-2n			50J1

93
41 52

	100%		36S4
I	9/2	S	34B1,47M27
μ	5.3	S	47M27
	σ's		
(th n,γ) 6.6^mNb	1.4		47A8
(~1Mev n,γ) 6.6^mNb	0.052		49H5

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$^{>93}_{41}$

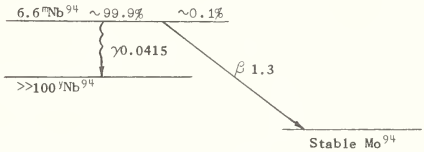
τ 30^m 49B29

β^- 49B29

Mo-d-α chem 49B29
Sample enriched in heavy Mo
Not observed in fission 49C20

$^{94}_{41}$ 53 -

τ_1 6.6^m 40S6



6.6ᵐNb produced by
Nb-n-γ 48G2
σ 49H5
Nb-d-p 46K1,46W2

τ_2 >>100^y for K capture 48G2

β^- ~0.1% 1.3 46G19

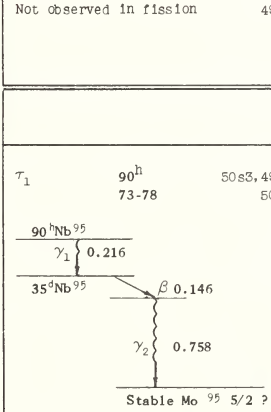
γ 0.0415 sc 49C1

Nb K_α X-ray 48G2

Mo^{96}-d-α produces no detectable Geiger activity 49B29

$^{95}_{41}$ 54

τ_1 90^h 50s3,49H31
73-78 50j1



No Nb K X-ray 49B29

90ʰNb produced by
Fission chem 50e4
Mo^{97}-d-α chem 49B29
90^hyield >> 35^dyield
Mo-d-α 50j1
Zr-d 50j1

d (1.4%) 65^dZr 49H31
d (2%) 65^dZr 50e2

τ_2 35^d 49H31,43E8
38.7 45P1

β- 0.146 s 49H31
0.15 s 50n2
0.14 a 48M1

γ_1 0.216 sc 49H31
α~∞ 49H31
0.24 sc 50l3
0.23 sc 50n1

γ_2 0.758 s 49H31
α~0.002 49H31
0.75 s 47R1
0.77 s 50n2
0.92 a coin 48M1

βγ coincidences 48M1
γγ coincidences also observed 48M1

35^dNb produced by
Fission chem 49G13,50g14
Mo^{97}-d-α chem 49B29
Mo-d-α 50j1
d (98.6%) 65^dZr 49H31
d (98%) 65^dZr 50b1,50e2
d 65^dZr 46G6

96 41 55				97 41 56				?		
τ	23.3^h		49K19	τ	76.0^m 75		48P3 40G4,50K3	τ	42^d	45W2
β^-	0.67	a	49K19	β^-	1.4	a	50K3			
γ	1.03	a	49K19	γ	0.78	a	50K3			
				Level	~0.8		Zr^{97}			
Zr^{96}-p-n	chem		49K19	Fission Mo-γ-p Mo-n-p	chem relσ, chem chem		40G4,41H5 47H4,48P3 40S8	Nb-e^-		45W2
				d 17^hZr			40G4,40S8,41H5	Not produced by Mo^{95}-d-α	chem	49B29

?										
τ	21.6^h		46W2	No Nb found in fission with τ between 10^m and 10^h, except 76^mNb^{97}			49C20			
β^-	1.2	a	46W2							
γ	0.6	a	46W2							
Nb-d-t threshold ~ 5-6 Excitation curve similar to that of 10.1^dNb			46W2 46W2 46W2							
Not produced by Zr^{92} or Zr^{91}-d Mo^{94}-d-α Nb-slow n's	chem		49K18 49B29 46W2							

Neutron Cross Sections for Natural Element		
σ_s coh 5.2 49S12		
σ_s bound 7.4 49S12		
$E_n = 0.025$ev		
σ_a 2.40 49P3		
3.01 49H2		
σ_s 6.7 37G1		
σ_t MoO_3 18.5 46D13		

91 42 49		92 42 50
τ_1 15.5^m 49D10, 48W13	τ_2 75^s 49D10	15.05% 49H3
17 39B5, 38S3, 49K19	73 48W13	15.8 46W3
β^+ 3.7 a 49D10	β^+ 2.6 a 49D10	
2.65 cc 40S8		
	γ 0.3 a 49D10	
No γ 49D10		
		Levels 1.1 Nb^{92}
		1.5 Tc^{92}
Mo^{92}-n-2n 49K19		
Mo-n-2n chem 37H4, 40S8		
threshold ~12-13 38S14		
Mo^{92}-γ-n chem 49D10		σ's (pile n,γ) 6.7^{h}Mo <0.001 47S33
threshold = 13.5 45B12, 49D10		
threshold = 13.28 for 15^mMo and 75^sMo 49H17	Mo^{92}-γ-n chem 49D10	
Mo-γ-n relσ 48W13	Mo-γ-n relσ 48W13	
Mo-d-p 46W2		
Nb-d-2n 46W2		
Not produced by Mo^{94}-fast n's 49K19	Not d 15.5^{m}Mo 49D10	

93
42 51

τ_1	6.75^h	49K27
	6.7	46K1
	7	44D9
IT		49K27
γ	0.3	49K27
	α very large	
	0.7, $\alpha = 0.005$	
	1.7, $\alpha = 0$	
γ's in cascade		49K27
Mo K_α X-ray		49K27
Nb-p-n	chem	46K1, 44D9
Nb-d-2n	chem	46K1, 46W2
Zr^{90}-α-n		49K27
Mo-d-p		46W2
Zr^{91}-α-2n		49K27
Mo^{94}-n-2n		49K27
Not found from		
Mo^{92}-n-γ		49D10, 49B44
$\sigma < 10^{-5}$		49B44
Mo^{94}-n-γ		49D10
Mo^{94}-γ-n		49D10
Mo^{92}-d-p		49K27

τ_2	$< 2^y$	49B44
γ		49B44
e^-		49B44
Nb K_α X-ray		49B44
Level	2.4 ?	Tc^{93}
Mo-n-γ		49B44

94
42 52

	9.35%	49H3
	9.1	46W3
Levels	?	Tc^{94}

95
42 53

	15.78%	49H3
	15.7	46W3
I	1/2 ? S	34G2
	5/2 or 7/2 S	50A3
Levels	?	Tc^{95}, Nb^{95}
	σ's	
(th n, γ)	13.4	49P3

96
42 54

	16.56%	49H3
	16.5	46W3
Levels	?	Tc^{96}, Nb^{96}
	σ's	
(th n, γ)	1	49P3
Mo-γ-n		49H17
threshold = 7.1, n's observed		

97
42 55

	9.60%	49H3
	9.5	46W3
I	1/2 ? S	34G2
	5/2 or 7/2 S	50A3
Level	0.78	Nb^{97}
	σ's	
(th n, γ)	2.3	49P3

98
42 56

24.00%		49H3
23.8		46W3
Level	?	Tc^{98}

σ's

(th n,γ) 68^hMo	0.4	47S33
(th n,γ)	<0.7	49P3
(~1Mev n,γ) 68^hMo	32mb	49H5

99
42 57

τ	68.3^h		49C7
	67		50k4, 39S4
	63.5		48W13
	64		40S8
β^-	0.24	a	48M15
~25%	~0.5	s	49M45
	1.03	a	48M15
	1.2	a	50k4
	1.22	s	49M45
$\beta\gamma$ coincidences only for 0.24β			48M15
γ	0.141	s	49M45
weak	0.181	s	
weak	0.360	s	
strong	0.726	s	
Each 0.726 γ followed by 0.141γ			
Fission	chem		49G13, 50k4, 41H7, 48SP
Mo^{98}-n-γ			47M20
Mo-n-γ	chem		40S8, 48M15
	σ		47S33
Mo-γ-n	relσ		48W13

γ	0.24 *	s	48M6
	0.75	s	
* Possibly due to impurity			
	0.139	s	49C7
	0.167	s	
	0.179	s	
	~0.78	a	
γ's of 0.770, 0.815, 0.840 found			47S12
Note γ's of Tc^{96}			
Tc K X-ray			47E1
Mo-d-p			39S4, 46W2, 47E1
Zr-α-n			47E1
Mo-n-2n	chem		40S8
	p (~10%) 5.9^hTc		39S4
	p (~90%) long Tc		39S4

100
42 58

9.68%		49H3
9.6		46W3

σ's

(th n,γ) 14.6^mMo	0.5	47S33
(th n,γ)	<1.0	49P3
(~1Mev n,γ) 14.6^mMo	15mb	49H5

101
42 59

τ	14.6^m		41M3
	14		42H6
β^-	1.0 ?	a	42M4
	2.2	a	42M4
	1.9	a	40S8
γ	~0.3 ?	a	42M4
	0.9	a	42M4
Fission	chem		41H7
Mo-n-γ	chem		40S8, 41M3
	σ		47S33
Mo^{100}-n-γ			47M20
Not produced by			
Mo-fast n's			40S8, 41M3
	p 15.0^mTc		40S4, 42M4, 41H7, 41B2

102
42 60

τ	12^m	41H7
	11	49B44
β^-		41H7
Fission	chem	49B44, 41H7
	p <25^sTc	41H7

103 42 61	104 42 62	105 42 63
		τ $\sim 5^m$ 47S34 short 43B3 β^- 43B3 Fission chem 43B3 p 4.4^hRu 43B3
No fission Mo with mass > 102 has $\tau > 2^m$ 49B45		

92 ? 43				92 43 49				93 43 50			
τ	47^m		48K26	τ	4.5^m		48M18,49B45	τ	2.7^h		39D1,48M18,48K26
K			48K26	K 20%			49B45	K 93%			48K26
e^- 5%	0.54	a	48K26	β^+	3.5	a	49B45	β^+	0.85	a	49B45
								7%	0.83	a	48K26
γ 15%	1.5	a	48K26	γ	1.5	a	49B45	γ	2.44	a	49B45
									2.0	a	48K26
Mo K_α X-ray			48K26	$\beta^+/\gamma \sim 1$			49B45	$e^-/\beta^+ = 0.05$			48K26
								Mo K_α X-ray			48K26
								Mo^{92}-p-γ	chem, relσ		48K26
								Mo^{92}-d-n	chem, relσ		48K26
									chem		48M18
Mo^{92}-p-n	chem, relσ		48K26	Mo^{92}-d-2n	chem		49B45	Mo-d-n	chem		39S4
Mo^{92}-d-2n	chem, relσ		48K26	threshold $\sim$ 10			49B45		Not produced by		
					chem, relσ		48K26	Nb-α			48K26
				Mo^{92}-p-n	chem, relσ		48K26				
				No Mo daughter			49B45	Not p 6.7^hMo			49B45

94 43 51								
τ_1	53^m		47G3	τ_2	$< 53^m$		48H5	
IT			48H5	K 65%			47G3	
γ	0.0334	sc	48H5	β^+	2.47	s	47G3	
					2.5	a	48M19	
K X-ray			49M44	γ	0.380	s	48H5	
					0.873	s		
					1.48	s		
					1.85	s		
					2.74	s		
					0.9	a	48M19	
				Mo K X-ray			48H5	
Mo-p-n			48H5					
Mo^{94}-d-2n			48M19					
				d 53^mTc			48H5	

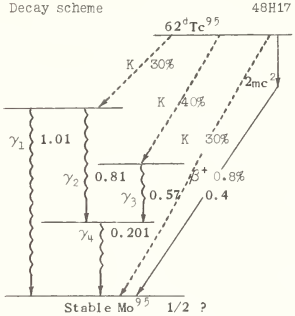
889592 O - 50 - 15

95
43 52

τ_1	20.0^h		48E3,48M19
K			48E3,48M2
γ strong	0.762	sc	48M2
	0.78	a	48E3
	0.8	a	48M19
	0.932	sc	48M2
γ	1.071	sc	48M2
X-ray			48E3,48M18
Level	0.95		Ru^{95}
Mo^{92}-α-p	chem		48E3
Mo-p-n	chem		48E3
Mo^{95}-d-2n	chem		48M19
Mo-d-n	chem		39S4
d 1.85^hRu			48E3

τ_2 62^d 52 — 39C2,49B45; 47E1

Decay scheme — 48H17



Mo^{95}-d-2n	chem		48M6
Mo-d-n	chem		39C2,48E1
Mo-p-n	chem		47E1

β^+	0.8%	0.4	cc	48H17
γ_1	~3%	1.017	sc,s	48H17
γ_2	~30%	0.81	sc,s	48H17
		0.8	a	48M6,47E1
γ_3	40%	0.570	sc,s	48H17
γ_4	70%	0.201	sc,s	48H17
		α=0.044		48H17
		0.2		48M6,47E1

$\gamma_3\gamma_4$, $\gamma_2\gamma_4$ coincidences — 48H17

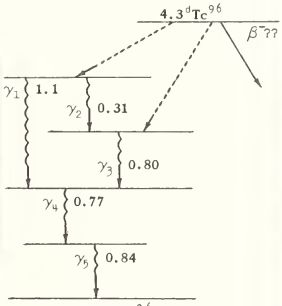
γ_4 twice as intense as γ_2 — 48M26

Mo K X-ray — 39S4

96
43 53

τ 4.3^d 4.2 — 47G4,47E1; 48M6

Decay scheme — 48M2



K			47E1
No β^+			48M2
β^- ??*	0.82	s	48M2
	0.64	a	47E1
γ_1 weak	1.119	sc,s	48M2
γ_2 weak	0.312	sc	48M2
γ_3 strong	0.806	sc,s	48M2
	0.8	a	48M6
γ_4 strong	0.771	sc,s	48M2
γ_5 strong	0.842	sc,s	48M2
γ	0.9	a	47E1

* Possibly due to scattered electrons — 48M2

$\gamma\gamma$ coincidences — 48M2

Order of γ_4, γ_5 unknown — 48M2

γ's of 0.815, 0.770, 0.840Mev found from spectrometer measurements. (Attributed to Mo^{99}.) — 47S12

Mo X-ray — 47E1

Mo^{96}-d-2n	chem	48M6
Nb-α-n	chem	47E1
Mo-p-n	chem	47E1
Mo-d-n	chem	47E1

97
43 54

τ_1	90^d		39C2, 48M6
	91		41H1
	95		47E1
IT			41H1
γ	0.097	sc	41H1
	0.097	ac	48M6
	α very large		48M6
	0.108	ac	47E1
	α large		47E1
Tc K X-ray			41H1
Mo^{97}-d-2n	chem		48M6
Mo-d-n	chem		37C3, 39C2
Mo-p-n	chem		47E1, 47G4
	d 2.8^dRu		47M5, 50s28
	p long Tc		49B42

τ_2	$>10^3{}^y$*		49B42
	>15*		41H1

* From decay of parent

	d 90^dTc		49B42

98 ?
43

τ	2.7^d		50g21
	2.8		48M19
β^-	0.75	a	50g21
	1.3	a	48M19
γ	1.0	a	50g21
	0.9	a	48M19
Mo^{98}-d	chem		48M19
Ru-n	chem		50g21

98 ?
43

τ	41^m		49B42
K			49B42
γ			49B42
Mo^{98}-d	chem		49B42

99
43 56

τ_1	5.9^h		50g4
	6.6		39S4
IT			39S4
γ_1	0.0018	pc	49M45
γ_2	0.1412	sc	49M45
	$\alpha = 0.1$	K/L = 8.1	49M45
$\gamma_1\gamma_2$ coincidences			49M45
No $\gamma\gamma$ or γe^- coincidences			48M15
Tc K X-ray			39S4
Fission	chem		40S2, 39H6, 48SP
Mo^{98}-d-n	chem		49B42
Ru-n-p	chem		46B21
	d (~10%) 68^hMo		39S4, 41H7
	p long Tc^{99}		39S4, 41H7

τ_2	$\sim 3\times10^5{}^y$		50s4
	9.4×10^5		47M15
β^-	0.30	s	49K34
	0.3	a	50l4, 50s4
	0.32	a	47M15
No γ			49K34, 47M15
Fission	ms		47I4
	chem		50l4, 50s4
Mo-n-$\gamma\beta$			47M15
	d (~90%) 68^hMo		39S4, 41H7
	d 5.9^hTc		39S4, 41H7

100 43 57				101 43 58				102 43 59			
τ	80^{s}		48M18	τ	15.0^{m}		49B42	τ	$<25^{s}$		49B44
					14.5		48P3		$<1^{m}$		41H7
					14.0		41M3				
					16.5		48M33				
β^{-}	2.3	a	48M18					β^{-}	3.7	a	49B44
				β^{-}	1.3	a	42M4		~ 5	a	41H7
γ	0.6	a	48M18		1.2	a	40S8				
								γ			41H7
				γ	0.3	a	42M4				
				Level			Mo^{101}				
Mo^{100}-d-2n			48M18	Fission	chem		41H7	Fission			41H7
				Ru-γ-p	rel yield		48P3				
					d 14.6^{m}Mo		39S4,40S8		d 12^{m}Mo		41H7

105 43 62				<101				<101			
τ	short		43B3	τ	36.5^{h}		39D1	τ	18^{s}		44D9
				β^{-}			39D1	β^{-}			44D9
Fission			43B3	Mo-p-n			47G4,39D1	Mo-p-n			38D2
	d $\sim 5^{m}$Mo		43B3								
	p 4.4^{h}Ru		43B3								

Neutron Cross Sections for Natural Element		
$E_n = 0.025$ev		
σ_a	2.5	49P3
	6.2	49H2
σ_s	5.6	37G1
σ_t	7.3	47GIF, 50Ad
Resonances		
E_o		
9.4 ev		47GIF, 50Ad
Others		47GIF, 50Ad
Graphs Available		
σ_t	0.015-500 ev	50Ad, 47GIF

95			
44	51		
τ	1.65^h		48E3
	1.6		48M33
K			48E3
β^+	1.1	a	48E3
γ	0.95	a	48E3
K X-ray			48E3
Mo^{92}-α-n	chem		48E3
Ru-n-2n			48E3
Ru-γ-n			48M33
p 20^hTc			48E3

96		
44	52	
	5.68%	44E1
σ's		
(th n,$\gamma\beta$)90^dTc	10mb	46B29

97			
44	53		
τ	2.8^d		48M33, 46S11
K			46S11
γ	0.23	a, ac	46S11
Tc K X-ray			46S11
$X/\gamma \sim 4$			46S11
Mo^{94}-α-n	chem		48E3
Ru-d-p			46S11
Ru-n-γ			46S11
Ru-n-2n			48E3
Ru-γ-n			48M33
p 90^dTc			47M5, 50s28

98		
44	54	
	2.22%	44E1
Level	1.0 ?	Tc^{98}

99
44 55

12.81% 44E1

100
44 56

12.70% 44E1

Level 0.6 Tc^{100}

101
44 57

16.98% 44E1

Level 0.3 Tc^{101}

102
44 58

31.34% 44E1

σ's

(th n,γ)42^{d}Ru	1.2	47S33

103
44 59

τ	42^{d}		46S11
	41		46B28
	40		50g5
	45		48M33
β^- ~50%	0.350	s	48H36
~50%	0.665	s	48H36
97%	0.2	a	50s5
3%	0.8	a	50s5
γ	0.239	sc	48H36
	0.312	sc	48H36
	0.56	a	50g5, 46G25
	0.54	a	50s5
No $\beta\gamma$ angular correlation			49G21

Fission	chem	42N3, 50g6, 49G13
Ru-d-p	chem	46B28, 46S11
Ru-n-γ	chem	48H36, 50s5
	σ	47S33
Ru-γ-n		48M33
Ru-n-2n		48E3
Mo-α-n	chem	48E3
p 57^{m}Rh		48H36, 50g5

104
44 60

18.27% 44E1

σ's

(th n,γ)4.4^{h}Ru	0.7	47S33

105 44 61				106 44 62				107 44 63			
τ	4.4^{h}		46B28	τ	1.0^{y}		50g5	τ	4^{m}		43B3, 50g6
	4.5		50s6, 50s7		290^{d}		48G4				
β^-	1.3	a	46B28	β^-	0.041	s	49M46	β^-	~4	a	43B3
	1.5	a	43B3								
	1.4	a	50s7								
γ	0.75	a	50s7								
	0.7	a	46B28								
No $\beta\gamma$ angular correlation			49G21								
Ru-n-γ	chem		46S11, 46B28								
	σ		47S33								
Ru-d-p	chem		50s8, 46S11, 46B28	Fission	ms		48H25	Fission			43B3
Fission	chem		49G13, 43B3, 41S6, 48SP		chem		50g7, 49G13				
	d short Mo		43B3								
	d short Tc		43B3								
	p 36.5^{h}Rh		46B28, 46S11		p 30^{s}Rh		50g5		p 24^{m}Rh		50g6, 43B3

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	150	49P3
	171	49H2
σ_s	~6	49M31
σ_t	155	44F12
	145	49M31

Resonance

E_o	σ_o	Γ	
1.21 ev	2750	0.21	49M31
1.30	>2500	<0.26	46B26
1.28		0.14	49G9

Graphs Available

σ_t	0.0044-330 ev	49M31
	0.015-5ev	50Ad, 47GIF, 47S31

99
45 54

τ	5^h	49E4
β^+	0.6	49E4
γ, e^-		49E4
Ru-p-n		49E4
Ru-α-p		49E4

100
45 55

τ	19.4^h		48L3
	21		50s29
K			48L3
β^+ 5%	3.0	s	48L3
25%	1.3		49E4
γ	1.2	a	48L3
	1.8	a	50s29
	1.55		49E4
e^-	0.6	s	48L3
Ru K X-ray			50s29, 49E4
Levels	0.09		Pd^{100}
	1.8		
Ru-d-n	chem		50s29
d 4^dPd			48L3

101
45 56

τ	4.3^d		48L3
	4.7		49E4
	5.9		50s30
K			48L3, 49E4
No β^+			48L3
γ	0.35	a, s	48L3
	α ~0.10 ?		48L3
	0.13	sc	49E4
	0.08	sc	49E4
K X-ray			48L3, 49E4
e^- possibly from 0.35γ			48L3
Ru-d-n	chem		50s30
Ru-p-n			49E4
Ru-α-p			49E4
d 9^hPd			49E4, 48L3

102
45 57

τ	215^d		47H5
	210		48M33, 41M2
K ?			50s31
β^+	1.3	a	50s31
	1.13	cc	45H1
β^-	1.04	cc	45H1
$\beta^-/\beta^+ = 1.2$			41M2
γ	~0.46	a	50s31
probably annihilation			50s31
Ru K X-ray			50s31
Rh-n-2n	chem		41M2
Ru-d-n			50s31
Rh-γ-n			48M33
Not produced by Fission			50s10

103
45 58

τ	57^m		50g5
	52		47F3
	45		45W3
IT			47F3, 47H5, 48G19, 50g5
e^-	0.034	sc	48H36
	only line found		48H36
	0.03	a	50g5
	0.042	a	47F3
	0.0399	sc	48G19
	0.0427	sc	48G19
Rh K X-ray			47F3, 47H5, 48G19, 50g5
Fission			50g5
Rh-n-n	σ		47F3
Rh-e^--e^-			45W3
Rh-γ-γ			45W3
Rh-p-p	relσ		48H36
Rh-d-pn			48H36
	d 17^dPd		47M12
	d 42^dRu		48H36, 50g5

	100%		43C1
Levels found in production of 57^mRh by Rh-γ-γ			
	1.26		45W3
	1.64		
	2.02		
	2.37		
	2.71		
	3.05		
	σ's		
(th n, γ) 4.3^mRh	12		47S33
(th n, γ) 44^sRh	137		47S33
($\sim$1Mev n, γ) 4.3^mRh	0.016		49H5
($\sim$1Mev n, γ) 44^sRh	0.103		49H5
(Ra-Be n, n) 57^mRh	$\sim$1		47F3
For other fast n values see			48WH
(50Mev d, 2n) 17^dPd	0.0024		48L3
(50Mev d, 4n) 9^hPd	0.24		48L3
(50Mev d, 5n) 4^dPd	0.28		48L3

104
45 59

τ_1	4.34^m		39R2
	4.37		39C3
	4.3		47F3
IT			38P2
e^-	0.070	sc	47H5
	0.087	ac	47F3
	0.070	ac	43A2
	0.046	sc	4003
	0.066	sc	4003
	0.086	sc	4003
γ	0.080	a	43A2
	$\alpha \sim 0.65$		43A2
	$\sim$0.05	a	43S4
Rh K X-ray			43A2
Rh-n-γ	σ		47S33
Pd-γ-p	relσ		47H4
Ru-p-n			44D9
	p 44^sRh		47F3, 38P2

τ_2	44^s		38P2
	42		39C3
β^-	2.6	s	47H5
	2.5	a	40M9
	2.3	cc	39C3
γ	0.041	a	47C11
	0.18	a	47C11
	0.95	a	47C11
Rh-n-γ	σ		47S33
Ru-p-n			36L1
Pd-γ-p	relσ		47H4
	d 4.3^mRh		47F3, 38P2

105
45 60

τ	36.5^h		50s6, 50s11
	37		46B28
	34		41N2
β^-	0.78	a	46B28
	0.60	a	50s11
	0.6	a	48K1
γ	0.33	a	50s11
	α large		50s11
Level	0.7		Ru^{105}
Ru-d-n			50s11
Rh-t-p	chem		48K1
Pd-γ-p			48P3
Fission	chem		46PP
	d 4.4^hRu		46B28, 46S11

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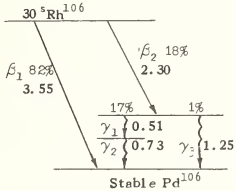
106
45 61

τ	30^s		50g5



β_1^-	82%	3.55	s	47P7
		3.5	a	49J3
		3.9	a	50g5
β_2^-	18%	2.30	s	47P7
		2.3	a	49J3
		2.8	a	50g5
γ_1		0.51	s	47P7
		0.3	a	50g5
γ_2		0.73	s	47P7
		0.8	a	50g5
γ_3		1.25	s	47P7

Fission	chem	46G6, 50g5
	d 1.0^y Ru	50g5

Angular correlation of γ's suggests I = 0, 2, 0 48B18

107
45 62

τ	24^m		43B3
	26		50g6
β^-	1.2	a	43B3
γ ?			50g6

Fission	chem	43B3
	d 4^mRu	50g6, 43B3

108 ?
45 63

τ	9^h		50b4
β^-	~1.3	a	50b4
γ	0.8	a	50b4

Fission	chem	50b4

109
45 64

τ	$<1^h$	50s12

No Rh with τ between 10^d and 100^y found in fission 50s10, 50s13

Neutron Cross Sections for Natural Element		
σ_s coh	5.0	49S12
σ_s bound	4.8	49S12
	$E_n = 0.025$ev	
σ_a	6.6	49P3
	8.8	49H2
σ_s	3	37G1
	Resonances	
E_o	Γ	
24ev	0.14	49G9
Attributed to Pd^{108}		49G9

100 46 54			
τ	4.0^d		48L3
K			48L3
γ	0.09	a	48L3
	1.8	a	48L3
X-ray			48L3
Relative abundances of Pd^{98} Pd^{99}, Pd^{100}, Pd^{101}	<0.0007%		49D7
Rh-d-5n	chem		48L3
p 19^hRh			48L3

101 46 55			
τ	9^h		48L3
K	~90%		48L3, 49E4
β^+	~10%	2.3 s	48L3
	~10%	0.53	49E4
No γ, no e^-			48L3
X-ray			48L3
Rh-d-4n	chem		48L3
Ru-α-n			49E4
p 4.3^dRh			49E4, 48L3

102 46 56		
	0.8%	36S4

103 46 57			
τ	17^d		46B19, 47M12
K			46B19, 47M12
No γ, no e^-			47M12
Rh K X-ray			48G19
Rh-d-2n	chem, σ		48L3
Rh-p-n			47M12
Pd-n-γ			46B19
p 57^mRh			47M12

104 46 58			
	9.3%		36S4
Levels	?		Rh^{104}
	σ's		
(6.6Mev p,n)		0.018	39E2

105
46 59

	22.6%	36S4
Levels	0.33	Rh^{105}
	?	Ag^{105}
σ's		
(6.6Mev p,n)	0.037	39E2

106
46 60

	27.1%	36S4
Levels	0.73 or 0.51	Rh^{106}
	1.25	Rh^{106}
	?	Ag^{106}
σ's		
(6.6Mev p,n) $8.6^{d}Ag^{106}$	0.0013	39E2
threshold = 3.9-4.3		39E2
(6.6Mev p,n) $24.3^{m}Ag^{106}$	0.055	39E2
threshold = 3.8		39E2

107
46 61

τ	7×10^{6} y	49P17
	$>3\times10^{8}$	50g8
	$>8.6\times10^{7}$	50l5
β^-	~0.035 a	49P17
Fission	chem	49P17

108
46 62

	26.7%	36S4
σ's		
(th n,γ) $13^{h}Pd$	11	47S33
(0.9Mev n,γ) $13^{h}Pd$	0.21	49B4
(6.6Mev p,n) $2.3^{m}Ag$	0.081	39E2

109
46 63

τ	13.1^{h}	48W13
	12.7	48P3
	14.1	48M33
	13	50s12
β^-	0.95 s	49S23
	1.0 a	46H4
No γ		50s12
No delayed βγ coincidences		49M28
Pd-n-γ	ms	46R3
	σ	47S33
Pd-γ-n	relσ	48W13, 48P3
Pd-d-p	chem, f	37K1
Ag-n-p		38F1
Ag-d-2p		46H4
Fission	chem	50s12, 49G13
p $39^{s}Ag$		49S23, 41S6

110
46 64

	13.5%	36S4
σ's		
(th n,γ) $28^{m}Pd$	0.39	47S33
(0.9Mev n,γ) $28^{m}Pd$	0.13	49B4

111 46 65			112 46 66			
τ	26^m	41S6	τ	21^h	50s12	
	17	37K1		17	41S6	
β^-	3.5 a	43B3	β^-	0.2 a	50s12	
			No γ		50s12	
Pd-d-p	chem	37K1				
Pd-n-γ	chem	37K1	Fission	chem	49G13, 48SP	
	σ	47S33				
Fission	chem	40N3, 41S6, 48SP				
	p 7.5^dAg	37K1, 41S6		p 3.2^hAg	40N3, 41S6, 50s12	

Neutron Cross Sections for Natural Element

σ_s coh	4.6	49S12
σ_s coh(Ag^{107})	8.7	49S12
σ_s coh(Ag^{109})	2.3	49S12
σ_s bound	6.6	49S12
$E_n = 0.025$ev		
σ_a	60	49P3
	89	49H2
σ_s	6	48WH
σ_t	65	46H33
Graphs Available		
σ_t	0.015-1,000ev	46H33, 47R6, 47GIF
	0.02-1.6Mev	49B28, 50Ad
	1-40Mev	50Ad
	0.025-11Mev	47GIF

Resonances

E_o	$\sigma_o\Gamma^2$	Γ	
5.1ev	300		47R6
5.1		0.12	49G9
5.6		~0.7	48C24
Assigned to Ag^{109}			49G9, 48C24
23		1-4	48C24
16	~24		47R6
Assigned to Ag^{107}			48C24
45	~700		47R6
90	Assigned to Ag^{109}		48C24
>115			49H16
>300			49H16

$E_n = 1$Mev

σ_t	~6.5	See graphs

102 47 55 or 104 47 57

τ	73^m	39E2
K		48L4
β^+		48L4
Pd-p-n	yield	39E2
Sb-d		48L4

103 47 56

104 47 57 or 102 47 55

τ	16.3^m	39E2
β^+ ?		39E2
Pd-p-n	yield	39E2

105 47 58

τ	45^d		47B16, 39E2
	40		49G24
K			39E2
γ	0.282	s	42D3
	0.345	s	42D3
	0.430	s	42D3
	0.650	s	42D3
	>1.0	s	42D3
	0.29	s	39E2
	0.42	s	39E2
	0.51	s	39E2
	0.62	s	39E2
K X-ray			39E2
Pd-p-n	f		39E2
threshold ~4			39E2
Rh-α-2n			47B16, 47L20
threshold = 16.2			47B16

106
47 59

τ_1	8.6^d		49G24
	8.2		38P3
K			44H1, 38F1
γ	0.505	s	42D3
	0.72 ?	s	42D3
	1.06	s	42D3
	1.63	s	42D3
	0.69	s	39E2
	1.06	s	39E2
$\gamma/X \sim 3$			39E2
$e^-/X = 0.2$			39E2
K X-ray			39E2
Pd-p-n	f		39E2
threshold = 3.9			39E2
Rh-α-n	f		47B16, 44H1
Ag-n-2n	chem		38P3
Cd-n-p	chem		38P3
Pd-d-n	chem		38P3

τ_2	24.5^m		38P3, 38D1
	24.3		48M33
	25		39E2
β^+	2.04	a	38F1
No γ			38F1
Pd-p-n	f		39E2
threshold = 3.8			39E2
Pd-d-n	chem		38P3
Ag-n-2n	chem		38P3
threshold = 5-7			38S14
Cd-n-p			38P3
Ag-γ-n			48M33, 39B5
threshold = 9.5			45B12
Ag-e^--e^-n	σ		48S3
threshold = 9.5			48S3
Rh-α-n			47B16, 39K1
threshold $\sim$ 11.5			47B16

107
47 60

τ	44.3^s		47B5
	40		41H3
IT			40A1
γ	0.0939	sc	47B5
	α = 16, K/L = 0.92		47B5
	0.093	sc	39V2, 41H1
	α = 99, K/L = 1		41H1
Ag-n-n			44F1
Ag-γ-γ			45T2, 45W1
threshold = 1.18			45W1
Ag-e^--e^-			45W1
d 6.7^{h}Cd			46H4, 47B5

	51.35%		48W9
I	1/2	S	49C3, 37J1
μ	-0.086	S	49C3
Levels	0.094		44^{s}Ag^{107} Cd^{107}
Levels found in production of 44^{s}Ag by Ag-γ-γ			45W1
	1.59		
	1.95		
	2.32		
	2.76		
	3.13		
May be in Ag^{109} or Ag^{107}			
	σ's		
(th n, γ) 2.3^{m}Ag	44		47S33
(th n, γ)	30		48H38
($\sim$1Mev n, γ) 2.3^{m}Ag	0.13		49H5
Other fast n values			49B4, 48WH
(16Mev e^-, e^-n) 24.5^{m}Ag	5.4x10^{-4}		48S3
Graphs Available			
(n, γ) 2.3^{m}Ag	0.003-6Mev		46L7, 47GIF, 50Ad

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47 61

τ	2.33^m		48P3
	2.3		48M33, 39B5
	2.4		44F1
β^-	2.8	cc	36N2
$\beta^+/\beta^- < 0.005$			47B8
Ag^{107}-n-γ			44F3
Ag-n-γ	σ		47S33
Pd-p-n	yield		39E2
Ag-γ-n			39B5
threshold = 9.3			45B12
	relσ		48P3, 48W13
Ag-e^--e^-n	σ		48S3
threshold = 9.3			48S3
Ag-d-p	chem		40K2
Cd-n-p	chem		38P3

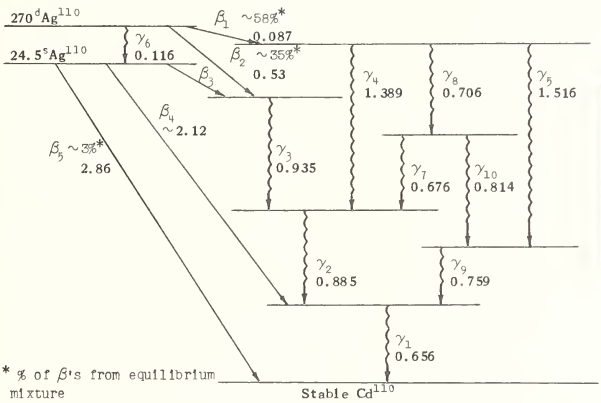
$^{109}_{47}Ag_{62}$

τ	39.2^{s}		47B5		48.65%		48W9
IT			41H3	I	1/2	S	49C3,37J1
γ	0.087	sc	46H4,49S23	μ	-0.159	S	49C3
	α = 11.5, K/L = 1.3		49S23				
	0.0890	sc	47B5				
	α = 19, K/L = 1		47B5				
				For possible levels see			Ag^{107}
				σ's			
				(th n,γ) 24.5^{s}Ag	97		47S33
				(th n,γ) 270^{d}Ag	2		47S33
				(th n,γ)	84		48H38
				(~1Mev n,γ) 270^{d}Ag	0.23		49H5
Ag-n-n			44F1	Other fast n values			49B4,48WH
Ag-γ-γ			45W1	(16Mev e^-,e^-n) 2.3^{m}Ag	7.9×10^{-4}		48S3
Ag-e^--e^-			45W1				
				Graphs Available			
	d 330^{d}Cd		46H4,41H3	(n,γ) 24.5^{s}Ag	0.003-6Mev		46L7,
	d 13^{h}Pd		49S23,41S6				47GIF,50Ad

110
47 63

τ_1	270^d	49G24	τ_2	24.5^s	47H4
	282	48C3		22	38P3
	225	38L4			

Decay scheme 50S1



$\beta\gamma$ and $\gamma\gamma$ coincidences support decay scheme 50S1

High energy β not in coincidence with any γ 49M38

β_1 and β_2 in coincidence with γ's 49M38

γ_1 and γ_2 in coincidence 49Y2
γ_5 not in coincidence with any γ 49Y2

No delayed coincidences with delay between 3×10^{-8} s and 10^{-3} s 49M26

270^dAg^{110} in equilibrium with 24.5^sAg^{110}

β_1^- ~58%	0.087	s	50S1
	0.09	a	49M38
	0.09	cc	49E1
β_2^- ~35%	0.530	s	50S1
	0.57	a	49M38
	~0.59	cc	49E1
β_3^- weak	soft		50S1
	0.19 ?	a	49M38
β_4^-	~2.12	s	50S1
β_5^- ~3%	2.86	s	50S1
	>2	a	49M38

Possibly one or more very weak β's 50S1

No β^+ 50S1

$\beta^+/\beta^- < 0.002\%$ 49E1

No K X-ray 47D8

γ_1	100% *	0.656	sc, s	50S1
		$\alpha = 2.5\times10^{-3}$		50S1
	100% *	0.66	sc	47R1
		0.66	a	49Y2
γ_2	81% *	0.885	sc, s	50S1
		0.9	a	49Y2
	110% *	0.9	s	47R1
γ_3	31% *	0.935	sc, s	50S1
γ_4	33% *	1.389	sc, s	50S1
	20% *	1.4	s	47R1
γ_5	17% *	1.516	sc, s	50S1
		1.48	a	49M38
γ_6	weak	0.116	sc	50S1
		α large, K/L ~1.3		50S1
γ_7	weak	0.676	sc, s	50S1
γ_8	weak	0.706	sc, s	50S1
γ_9	weak	0.759	sc, s	50S1
γ_{10}	v. weak	0.814	s	50S1
γ		$1.63 < E_\gamma < 2.3$		49D23

* relative %

24.5^sAg^{110}

β^-	2.6	a	46H6
	2.8	cc KU	36G1

24.5^sAg^{110} produced by

Ag^{109}-n-γ		44F3
Ag-n-γ	σ	47S33
E_γ(max) = 6.5		49K15
Cd-γ-p	relσ	47H4
Cd-n-p		38P3

Not produced by

Pd-6.5Mev p	39E2

270^dAg^{110} produced by

Ag^{109}-n-γ		46G15
Ag-n-γ	σ	47S33
Ag-d-p	chem	44H2

Resonance for production of 270^dAg by n-γ same as that for production of 24.5^sAg 46G4

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111
47 64

τ	7.5^{d}		38P3
	7.6		49D6,50S24
β^- simple	1.06	s	49H6
	~0.2	a	50S24
	1.0	a	50S24
No γ			38P3

Number of coincidences as function of delay time (see Cd^{111}) indicates that Ag^{111} decays directly to ground state of Cd^{111} 49M26

See Cd^{111} for Ag, Cd, In relationships

Pd-d-n	chem	38P3
Pd-α-p	chem	38P3
Cd-n-p	chem	38P3
Cd-γ-p	chem, relσ	49D6,47H4
Fission	chem	49G13,50S24
Ag-t-p		47K2
	d 26^{m}Pd	41S6,37K1,50S24

112
47 65

τ	3.2^{h}		49D6,38P3
β^-	3.6	a	50S12
	2.2	cc	38P3
γ	0.86	a	50S12

Cd-n-p	chem	38P3
In-n-α	chem	38P3
Cd-γ-p	chem, relσ	49D6,47H4
Fission	chem	50S12,49G13,48SP
	d 21^{h}Pd	41S6,40N3,50S12

113
47 66

τ	5.3^{h}		49D6,47T13
β^-	2.1	a	49D6
	2.2	a	47T13
No γ			49D6,47T13

Cd^{114}-γ-p	chem, relσ	49D6
Fission	chem	47T13

114
47 67

τ	2^{m}		49D6
β^-	hard		49D6

Cd^{114}-n-p	chem	49D6
Fission		47S34

115
47 68

τ	20^{m}		49D6
	22		47T13
	~20		47S34
β^-	~3	a	49D6,47T13
	~2		47S34
No γ			49D6

Cd^{116}-γ-p	chem, relσ	49D6
Fission	chem	47S34,47T13

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	3170	49H2
	3500	49P3
σ_s	~6.5	(48WH)
σ_t	2400	See graphs

Resonances

E_o	σ_o	Γ	
0.17ev	7200	0.115	47R6
0.180	7800	0.122	47Z1
0.178	7250	0.110	47S32
Assigned to Cd^{113}			46M12, 47D2
110ev			48C24
Assigned to Cd^{116}			48C24

$E_n = 1$Mev

σ_t	~6.7	48H15

Graphs Available

σ_t	0.008-100ev	47GIF, 47R6
	0.023-15Mev	50Ad, 47GIF

105 (48 57)

τ	33^m	37P2
	38	48M33
	57	49G24
β^+	1.5	49G24

Cd-n-2n	chem	49G24, 37P2
Cd-γ-n		48M33
Pd-α	chem, relσ	49G24

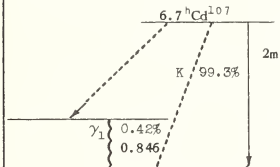
106 (48 58)

1.22%	49H3, 48W9
1.215	48L5

107 (48 59)

τ	6.7^h	39D1

Proposed decay scheme 45B4



β^+	0.31%	0.32	s	45B4
γ_1	0.42%	0.846	s	45B4
		$\alpha \sim 10^{-3}$		45B4
		0.7	a	41H1
γ_2		0.0939	sc	47B5
		$\alpha = 16$, K/L = 0.92		47B5
		$\tau = 44.3^s$		47B5
		0.093	sc	39V2, 41H1
		$\alpha = 99$, K/L = 1		41H1

$K/\beta^+ = 320$, in agreement with Fermi theory 45B4

Ag K X-ray 45E4

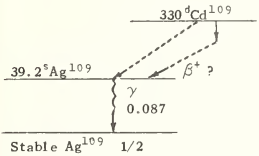
Cd^{106}-n-γ		46H4, 46G15
Ag-d-2n	chem	49C29, 41H3
Ag-p-n	chem	39V2, 39D1, 49C29
threshold ~2.4		39D1
Pd-α	relσ	49G24
p 44.3^sAg		46H4, 47B5

108 (48 60)

0.89%	49H3
0.875	48L5
0.98	48W9

$^{109}_{48}$ 61

τ	330^d		46B2
	470		49G24
	158		41H3



β^+ ?			48C23
γ	0.087	sc	46H4, 49S23
	α = 11.5, K/L = 1.3		49S23
	0.089	sc	47B5
	α = 19, K/L = 1		47B5
	τ = 39.2^s		47B5
Cd^{108}-n-γ			46G15, 46H4
Ag-d-2n	chem		49G24, 41H3
Ag-α-pn			46H4
Ag-p-n	chem		45B3
Pd-α	relσ		49G24
	p 39.2^{s}Ag		41H3, 46H4

$^{110}_{48}$ 62

	12.43%	49H3
	12.39	48L5
	12.35	48W9

Levels	0.66	Ag^{110}
	1.42	
	1.54	
	2.22	
	2.48	
	2.93	

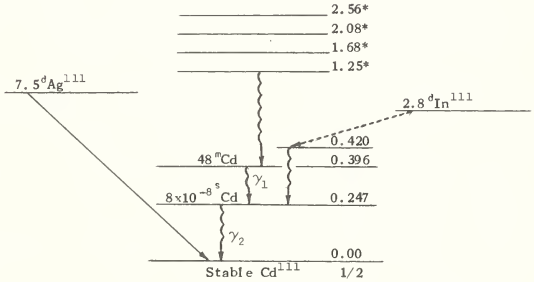
σ's

(th n, γ) 49^{m}Cd	0.2		48G2
(6.9Mev p, n) 65^{m}In	0,03		39B3

$^{111}_{48}$ 63

τ	48.7^m		44W1
	48.6		49H6
γ_1	0.149	s	49H6
	α large		49H6
	0.146	sc	48H37
	α > 12, K/L ~ 1.8		48H37
γ_2	0.247	s	49H6, 40L7, 49B8
	α ~ 0.1		49H6
	K/L = 5.4		40L7
	α = 0.04, K/L = 6		49B8
	0.238	sc	48H37
	α ~ 0.19, K/L > 10		48H37
	τ = 0.08$^{\mu s}$		49D26
	τ = 0.09		49M26
Fission	chem		40N3
Cd^{110}-n-γ			48G2, 49M26
	σ		48G2
Pd^{108}-α-n			48H22
Cd^{112}-n-2n			48H22
Ag-α-pn			48H22
Cd-γ-γ			45T2, 44W1
Cd-e^--e^-			44W1
Cd-n-n			48H37

	12.86%		49H3
	12.75		38L5
	12.78		48W9
I	1/2	S	29S1, 33S2, 31S1
μ	-0.65	S	33J2, 36B6



* Levels for production of 48^{m}Cd by Cd-γ-γ and Cd-e^--e^- 44W1

σ's

(6.9Mev p, n) 2.8^{d}In	8mb		39B3

112
48 64

	23.79%	49H3
	24.07	48L5
	24.00	48W9
Level	0.86	Ag^{112}

σ's

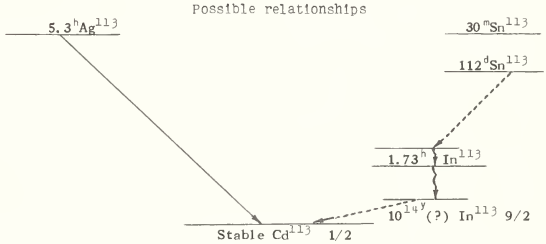
(6.9Mev p,n) 23^mIn	0.02	39B3

Cd-γ-n n's observed	49H17
threshold = 6.4	49H17

113
48 65

	12.34%		49H3
	12.26		48L5
	12.30		48W9
I	1/2	S	29S1, 31S1, 33S2
μ	-0.65	S	33J2, 36B6

Possible relationships



σ's

(th n,γ) ~20,000	46M12, 47D2	
Cd^{113} responsible for large Cd thermal σ. Other main isotopes have < 1/40 this σ.	46M12, 47D2	
(6.9Mev p,n) 1.73^{h}In	0.02	39B3

113 ?
48 65 ?

τ	2.3^m	48H22
Cd^{113}-n-n		48H22
Cd-n-γ		47S1
σ(atomic) = 0.05		47S33
Not produced by Cd^{112}-n-γ		49G8

?
48

τ	5^y	49G24
β^- or e^-	0.45	49G24
No γ		49G24
Cd-d	chem	49G24
Cd- fast n	chem	49G24

114
48 66

	28.81%	49H3
	28.86	48L5
	28.75	48W9
Levels	0.55	In^{114}
	1.27	

σ's

(th n,γ) 43^dCd	0.14	47S1
(th n,γ) 2.3^dCd	1.1	47S1
(6.9Mev p,n) 72^sIn	~0.03	39B3
(6.9Mev p,n) 50^dIn	0.03	39B3

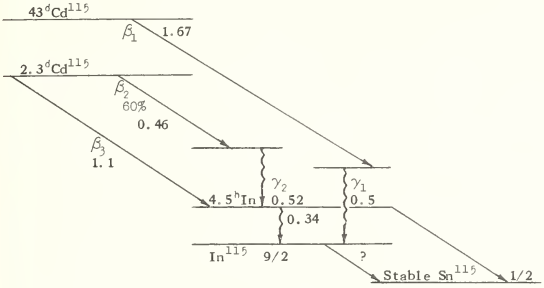
Cd-n-γ

E_γ (max) = 8.7		49M14
7.0		49K15
~7.9		49H9

115
48 67

τ_1	43^d	50s27
	44	50g18

τ_2	2.33^d	40L7, 50m6
	2.4	48M33



43^dCd^{115} produced by

Cd-d-p	chem	39C4
Cd-n-γ	chem, σ	47S1, 50s27
In-n-p	chem	50s27
Fission	chem	49G13, 50m7, 48SP

2.33^dCd^{115} produced by

Cd-d-p	chem	39C4
Cd-n-γ	chem, σ	47S1, 39G2
Cd-n-2n	chem	39G2
In-n-p	chem	50s27
Cd-γ-n		48M33
Fission	chem	49G13, 40N3, 48SP
	p 4.5^hIn	39C4, 49H7

43^dCd^{115}

β_1^- simple	1.67	s	49H7
	1.75	a	50g18
γ_1	~0.5	a	50s27
γ_1/β_1 ~1			50s27
No delayed coincidences with τ between 3×10^{-8} s and 10^{-3} s			49M26

2.3^dCd^{115}

β_2^-	0.46	a $\beta\gamma$	49M6
60%	0.56	a	50m6
β_3^-	1.10	s	49H7
	1.13	s	40L7
γ_2	0.520	s	49H7
	0.65	s	43M4
$\beta\gamma$ and $\gamma\gamma$ coincidences			49M6
No $\beta\beta$ coincidences			49M6

116
48 68

7.66%		49H3
7.58		48L5
7.63		48W9
σ's		
(th n,γ) 2.7^hCd	1.4	47S1
(6.9Mev p,n) 54^mIn	0.03	39B3
Resonance at 110ev		48C24

117
48 69

τ	2.72^h		50m8
	2.8		40L7
β^-	1.3 - 1.7	s	40L7

Cd-d-p	chem	39C4
Cd-n-γ		37M3, 39G2
	σ	47S1
Fission	chem	40N3
	p 1.95^hIn	40N3, 39G2, 40L7

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	191	49P3
σ_s	2.2	44B6
σ_t	194	44F12
	190	See graphs

Resonances

E_o	σ_o	Γ	$\sigma_o\Gamma^2$	
1.44ev*			~210	47H25
1.44	26,400	0.085		46M18
1.39	>15,000	<0.15		46B26
3.8			~120	47H25
3.7				46M18
8.6			~300	47H25
9.0				46M18

* Scattering resonance also 47L21

Graphs Available

σ_t 0.017-1000ev 47H25,46M18,47GIF

See also 49H16

0.02-1.6Mev 49B28,50Ad

107 ?
49

τ	33^m		49M20
β^+	2	s	49M20
γ			49M20
Cd^{106}-d	chem		49M20
Cd^{106}-p	chem		49M20

Not produced by

Cd^{108}-p		49M20
Cd^{108}-d		49M20

108
49 59

Activity of half-life < 1^h, $\beta^+ \sim 2$, γ, produced by Cd^{108}-d and assigned to In^{108}. This activity is daughter of 4.5^hSn. 49M20

Activity of half-life $\sim 5^h$, no β^+, $\gamma \sim 0.65$, produced by Ag-α and assigned to In^{108}. 48G7

109
49 60

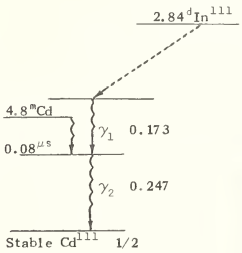
τ	4.3^h		49M20
	5.2		48G7
	6.5		47T2
K			47T2
β^+	0.75	a	49M20
γ	0.5		48G7
$K/\beta^+ = 8$			49M20
Ag-α-2n	ms, chem, f		48G7
	chem, f		47T2
threshold	~13.5		48G7
	~13		47T2
Cd^{106}-α-p	chem		49M20
Cd^{108}-d-n	chem		49M20
Cd^{108}-p-γ	chem		49M20

110
49 61

τ	65^m		48G7,39B3
	66		47T4
	72		48L4
β^+	1.7		48G7
	2.0	s	40L7
	2.2	a	48L4
Ag-α-n	ms		48G7
	chem, f		47T4,48G7
threshold	~11		48G7
	~12		47T4
Cd-p-n	chem, σ		39B3
Cd-d-2n			40L7
d 4.5^hSn			48L4

111
49 62

τ	2.84^d	49H6
	2.7	38B3, 39C4



Ag-α-2n	ms	48G7
	chem, f	47T4, 48G7
threshold = 15.5		47T4
~15		48G7
Cd^{108}-α-p	chem	49M20
Cd-p-n	chem, σ	39B3
Cd-d-n		39C4
In-n-3n		40L7

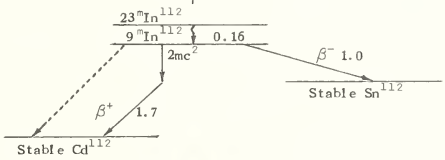
2.84^{d}In^{111}

K			40L7
No β^+			48G7
γ_1	0.173 s	49B8, 49H6,	40L7
	α = 0.18		49H6
	α = 0.09, K/L = 9		49B8
	K/L = 7		40L7
γ_2	0.247 s	49B8, 49H6,	40L7
	α ~ 0.1		49H6
	α = 0.04, K/L = 6		49B8
	K/L ~ 5		40L7
	τ = 0.08$^{\mu s}$		49D26
	0.09		49M26
Angular correlation of γ's			49B19

See also Cd^{111}

112
49 63

τ_1	23^m	47T2	τ_2	9^m	47T4
	20	39B3			



IT		47T4	K		47T4
γ	0.16 a	47T4	β^+	1.7 a	47T4
	α large	47T4		1.7 cc	40L7
	0.16 sc	39B3	β^-	1.0 a	47T4
In K X-ray		47T4	Cd K X-ray		47T4
Ag-α-n	chem, f		Ag-α-n		47T4
threshold ~ 12		47T4	In-n-2n		47T4
In-n-2n					
Cd-p-n	chem, σ	39B3			
Cd-d-n	chem	40L7	d 23^mIn		47T4, 48G3

113
49 64

τ_1	1.73^{h}		40L7
	1.75		39B3
γ	0.39	sc	40L7, 39B3
	$\alpha = 0.7$		39B3
	K/L = 5.4		40L7
In K X-ray			39B3

See Cd^{113} for possible Ag, Cd, In, Sn relationships

Cd-p-n	chem, σ		39B3
Cd-d-n	chem		40L7
In-γ-γ			45D2, 47D3
In-n-n	σ		48C19
d 112^{d}Sn			39B3

	4.16%		49H3
	4.23		48W9
τ_2	$\sim 10^{14}y$*		49C30
I	9/2	M	42H7
		S	37B8
μ	5.46		49Po
		M	42H7, 49T1
q	1.144	M	50M2

σ's

(th n, γ) 72^{s}In	2.0	48G2
(th n, γ) 50^{d}In	56	47S33
(n, n) 1.73^{h}In similar to that for In^{115} (n, n) 4.5^{h}In		48C19
(6Mev p, n) 112^{d}Sn	0.03	39B3
(γ, γ) 1.73^{h}In same as that for In^{115} (γ, γ) 4.5^{h}In		47D3

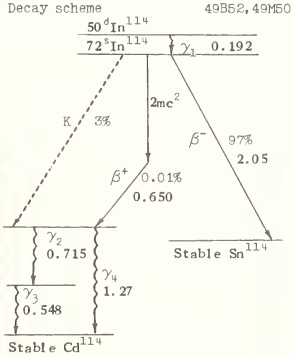
L capture*	pc	49C30
No K capture*		49C30

* Preliminary work

114
49 65

τ_1	50^{d}		49B52, 37L5
	49		48W13, 39B3
γ_1	0.192	s	40L7, 49B52
	$\alpha = 4$, K/L = 1.1		49B52
	$\alpha = \infty$, K/L = 1.0		40L7
	0.191	sc	48C23
	0.190	s	49M50
	0.196	s	49M38
	$\alpha = 9$		49M38
In-n-γ			49M38, 49M50
	σ		47S33
In-γ-n	relσ		48W13
In-n-2n	chem		40L7
In-d-p	chem		40L7
Cd-d-n	chem		40L7
Cd-p-n	chem, σ		39B3
p 72^{s}In			40L7, 48G3

Decay scheme 49B52, 49M50



γ_2 and γ_3 in cascade	49B52, 49M38
No β^-e^- coincidences	49M38
No $\beta^-\gamma$ coincidences	49M13, 49M38
$\gamma\gamma$ coincidences	49M13
$\beta^+/\beta^- = 10^{-4}$	49B52

τ_2		72^{s}		48W13, 39B3
K	3%			49B52
	4%			49M50
β^+	0.01%	0.650	s	49B52
β^-		2.05	a	49M38
		1.98	a	48C23
		1.89	a	49M13
γ_2	3%	0.715	s	49B52
		0.722	s	49M50
γ_3	3%	0.548	s	49B52
		0.552	s	49M50
γ_4	~0.03%	1.27	s	49M50
		1.3	a	49M38
Cd K X-ray				49B52
In^{113}-n-γ		σ		48G2
In-γ-n		relσ		48W13
In-n-2n				40L7
threshold = 12-13				38S14
Cd-p-n		σ		39B3

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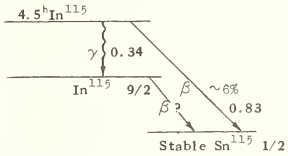
115
49 66



τ		4.50h	47D3
		4.53	40L7
β^- ~6%		0.83 s	49B53
γ		0.338 sc	40L7,49B53
		α~1, K/L~5	40L7
		α=0.33	49B15
		0.337 sc	49H7
β^-/e^-=0.13			49B53
X-rays account for all $e^-\gamma$ and $\gamma\gamma$ coincidences			49M6
Levels found in production of 4.5hIn by In-γ-γ and In-e^--e^-			
		1.04	49M7
		1.42	49M7
		2.13	43W4
		2.64	43W4
Fission	chem		39G2,40N3
In-d-d	σ		49M7
In-α-α	chem,σ		40R7
In-e^--e^-	σ		49W4
In-γ-γ			43W4,49W4
In-p-p	chem,σ		39B3
In-n-n			39G2
	σ,f		48C19
Cd-d-n	chem		40L7
	d 2.3dCd		39C4,49H7

		95.84%	49H3
		95.77	48W9
I	9/2	M	42H7
		Z	39M5
		S	34P1,33J3
μ	5.475		49Po
		M	42H7,49T1
q	1.161	M	50M2
	1.17	Z	39H12(48F6)
β^-	(preliminary result)		49C30
	σ's		
(th n,γ)54mIn		145	47S33
13s In		52	47S33
(~1Mev n,γ)54mIn		0.18	49H5
13s In		0.063	49H5
Other fast n values			49B4,48WH
(~3Mev n,n)4.5hIn		0.36	48C19
(5.8Mev p,p)		3×10^{-5}	39B3
(2Mev d,d)		$<10^{-6}$	49M7
(16Mev α,α)		3×10^{-4}	40R7
(1.2Mev e,e)		$\sim10^{-9}$	49W4
(γ,γ)			49M7,47D3
Graphs Available			
σ(n,γ)54mIn		0.003-6Mev	46L7,47GIF, 50Ad
		0.5-4Mev	48C19

116
49 67

τ_1	54.31^m		45R2
	54.05		47G16
	53.93		49S2
β^-	0.85	s	39C4
simple	0.7	a$\beta\gamma$	48M11
γ	0.428	s	42D3
	1.12	s	
	1.31	s	
	2.32	s	
< 1% above D-γ-n threshold			47W1
1-10% above Be-γ-n threshold			47W1
Other γ values		cc	40C8
Cd-p-n	chem, σ		39B3
In-d-p			37L5
In-n-γ	σ		47S33

τ_2	13^s		35A1, 39C4
β^-	2.95	a	40L7 (46B27)
No γ			38M2
Cd-p-n			44D9
In-d-p			37L5
In-n-γ	σ		47S33
Sn-γ-p	relσ		47H4

117
49 68

τ	1.95^h		40L7
	1.90		50M8
β^-	1.73	s	39C4
	1.95	a	50M8
No γ			40L7
Fission			48SP
Cd-d-n	chem		39C4, 40L7
Sn-γ-p	relσ		47H4
	d 2.7^{h}Cd		39G2, 40N3, 40L7

118
49 69

τ	4.5^m	49D4
β^-	1.5	49D4
γ		49D4
Sn^{119}-γ-p		49D4

119
49 70

τ	17.5^m	49D4
β^-	2.7	49D4
No γ		49D4
Sn^{120}-γ-p		49D4

Neutron Cross Sections for Natural Element			? ? 50			111 ? 50 61 ?		
σ_s coh	4.6	49S12	τ	4.5^h	49M20,48L4	τ	35.0^m	49H10
				3	39L4			
σ_s bound	4.9	49S12						
	E_n = 0.025ev		K		49M20,48L4	β^+	1.45	49H10
σ_a	0.58	49P3						
	0.71	49H2				X-ray		49H10
σ_s	4.3	(48WH)						
σ_t	4.6 ce	See graphs						
	Resonances							
E_o	6 ? ev	48H46						
	50 ? ev							
	100 ? ev							
	E_n = 1Mev							
σ_t	6.5	See graphs						
			Cd^{106}-α	chem	49M20			
	Graphs Available		Sb-d		48L4			
σ_t	0.01-200ev	47GIF,50Ad		Not produced by		Cd-α-n	chem	49H10
	0.013-10,000ev	48H46	Cd^{108}-α		49M20	Enriched material used but details not given. Note Sn^{113}		
	0.023-~14Mev	47GIF	Cd^{110}-α		49M20			
	0-1.5Mev	50Ad	Cd-α		39L4			
	1-300Mev	50Ad		p $<1^h$In	49M20			
				p 65^mIn	48L4			

112 50 62			113 50 63					
	1.01%	49H3	τ_1	$30\text{-}33^m$	49N10	τ_2	112^d	49N9
	0.90	48W9		25	39L4		~100	39B3
	0.94	48H44					70	39L4
			K ?		49N10	K		39B3
			β^+	1.2 a	49N10	γ	~0.09 a	49N9
							0.085 s	39B3
			e^-		39L4	No γ		47C4
			X-ray		49N10	In K X-ray		39B3,47S33
			See Cd^{113} for diagram of possible relationships					
	σ's							
(th n,γ) 112^dSn	1.1	47S33				Sn^{112}-n-γ		49N9
						Cd-α-n	chem	39L4
						In-p-n	chem,σ	39B3
			Sn^{112}-n-γ		49N9	In-d-2n	chem	47C4
			Cd-α-n	chem	39L4	Sn-d-p	chem	47C4
						Sn-n γ	σ	47S33
						Sn-γ-n		48M33
							p 1.73^hIn	39B3

114
50 64

	0.68%	49H3
	0.61	48W9
	0.65	48H44

115
50 65

	0.35%		49H3,48W9
	0.33		48H44
I	1/2	S	49G2
μ	-0.86	S	49G2

116
50 66

	14.28%	49H3
	14.07	48W9
	14.36	48H44
Level	0.7	Sb^{116}
	others ?	In^{116}

117
50 67

τ	14.5^d		49M51
	14		48L4
	13		39L4
γ	0.175	sc	49M52
	$\alpha \sim 1$		49M52
	0.17	a	48L4
	0.159	a,s	49M51
	0.162	a,s	49M51
Sn X-ray			49P10,49M52
Cd^{114}-α-n	chem		
Sn^{116}-d-p	chem		
Sn^{118}-n-2n	chem		49M52
Sn^{117}-n-n	chem		
Cd^{116}-d-n	chem		
Sn^{116}-n-γ			49M51
Sb-d-α			48L4
Cd-α-n	chem		39L4

	7.67%		49H3
	7.54		48W9
	7.51		48H44
I	1/2	S	33S3,34T1
μ	-0.9948		49Po
		I	49P11
		S	34T1
Levels	0.156 ?		Sb^{117}
	~0.5 ?		

118
50 68

	23.84%	49H3
	23.98	48W9
	24.21	48H44
Levels	?	Sb^{118}
	σ's	
(th n,γ)$\geq 100^d$Sn	0.02	49M51
Sn-γ-n (n's observed) threshold = 6.5		49H17

119
50 69

τ	$\geq 100^d$		49M51
γ	0.069	a,s	49M51
Sn^{118}-n-γ	σ		49M51
Sn-γ-n			48M33

	8.68%		49H3
	8.62		48W9
	8.45		48H44
I	1/2	S	33S3,34T1
μ	-1.0410		49Po
		I	49P11
		S	34T1

120
50 70

	32.75%	49H3
	33.03	48W9
	33.11	48H44
Level	1.1?	Sb^{120}

σ's

(th n,γ)27^hSn	0.22	47S33
(18Mev d,p)27^hSn	0.02	48L2
(18Mev d,2n)6^dSb	0.1	48L2
(18Mev d,2n)17^mSb	0.1	48L2
(18Mev d,3n)39^hSb	~0.02	48L2

121
50 71

τ	27.0^h		49N1
	26.4		49L5
β^-	0.383	s	49D15
	0.35	a	49L5
	~0.4	a	49N11,48L2
No γ			49N6,48L2,49D15
No e^-			49M51

62^hSn activity reported in 46PP probably due to $27^h Sn^{121}$ activity 49S45

Sn^{120}-n-γ	chem		49L5,49N11,49D15
Sn^{120}-d-p	chem,σ		48L2
Sn^{122}-n-2n			49L5
Sb-n-p			49N6
Not produced by			
Sn^{122}-slow n's			49L5
Sn^{124}-slow or fast n's			49L5

τ	long	49K34
β	0.41	49K34
Sn^{120}-n-γ		49K34

41^m activity with β~2.5, γ=0.25 produced by

Sn^{120}-d	49N6
Assigned to Sn^{121}	49N6
Not produced by	
Sn^{120}-n-γ	49N1
Sn^{120}-d-p	49L5

122
50 72

4.74%	49H3
4.78	48W9
4.61	48H44

σ's

(th n,γ)40^mSn	0.30	47S33

123
50 73

τ_1	130^d		49L5,49M51
	136		49N1,46G6
β^-	1.42	s	49B58
	1.3	a	49L5
	~1.5	a	49N6
γ	0.394	s,a	49M51
weak			49N9
No γ			49L5,49N6
No X-ray			49N6
Sn^{122}-n-γ	chem		49L5,49N9
Sn^{124}-n-2n	chem		49L5
Sn^{122}-d-p	chem		49L5
Sb-n-p			49N6
Sb^{124}-d-t			49N6
Fission	chem		50L8,48G4,48SP

τ_2	39.5^m		49D15
	41		49N11
	40		49L5,39L4
β^-	1.26	s	49D15
	1.12	a	49N9
	1.32	a	49L5
	~1.7	a	49N6
γ	0.153	sc	49D15
	~0.17	a	49N6
	~0.4	a	49N9
Sb K X-ray			49N9,49N6
βe^- coincidences			49D15
$e^-/\beta = 0.11$			49D15
Sn^{122}-n-γ			49L5,49N9,49D15
Sn-γ-n			48M33,49H17
threshold = 8.5			49H17
relσ			48W13
Sn^{124}-n-2n			49L5
Sn^{124}-d-t			49N6
Not produced by			
Sn^{120}-slow n's			49L5
Sn^{124}-slow n's			49L5
No Sb daughter with $\tau < 10^y$			49N6

124
50 74

	6.01%		49H3
	6.11		48W9
	5.83		48H44
τ	$0.4\text{-}0.9\times10^{16}{}^y$		49F4
β^-	1.0-1.5		49F4
Double β decay			49F4

σ's		
(th n,γ)10^mSn	0.6	47S33
	0.8	49S8
(th n,γ)10^dSn	0.15	47S33

125
50 75

τ_1	10.0^d		49L5
	9.9		49B58
	11		43H8,46S13
β^-	2.38	s	49N6
	2.34	s	49B58
	2.1	a	49L5
	2.6	a	50S16
γ ?			49N6
No γ			49B58
No X-ray			49N6
X-ray			47C4
Sn^{124}-n-γ			49N1
Sn^{124}-d-p	chem		49L5
Sn^{124}-fast n-γ	chem		49L5
Fission	chem		50S16,48S8,43H8
Sn-d-p	chem		47C4
Sn-n-γ	chem		39L4
	σ		47S33
p 2.7^ySb			49N1
No Sb daughter with $\tau < 50^y$			49N6

τ_2	9.5^m		49N9,49D27
	9.8		49L5
	10		47S21
β_1^-	2.04	s	49D27
	2.05	a$\beta\gamma$	49N9
	~2.2		47S21
β_2^-	1.17	s	49D27
β_3^-	0.51 ?	s	49D27
	0.5	a	49N1
γ_1	0.326	sc,s	49D27
	0.36	a$\beta\gamma$	49N1
γ_2	1.86	a$\beta\gamma$	49N1
	>1		49D27
Sn^{124}-n-γ			49D27,49L5,49N9,49S8
Sn-d-p	chem		39L4
Sn-n-γ	chem		47S21,39L4
	σ		47S33,49S8
Not produced by			
Sn^{120}-slow n's			49L5
Sn^{122}-slow n's			49L5

126
50 76

τ	70^m		42N3,43H8
	80		45S13
β^- 60%	0.7		50S16
40%	2.7		50S16
γ	~1.2		50S16
Any of these radiations may be due to 60^mSb^{126}			50S16
Fission	chem		42N3,43H8
p 60^mSb			46PP,42N3,43H8

Neutron Cross Sections for Natural Element		
σ_s coh	3.7	49S12
σ_s bound	4.2	49S12
	E_n = 0.025ev	
σ_a	5.3	49P3
	8.3	49H2
σ_s	4.3	(48WH)
σ_t	8.3	47R6
	Resonances	
E_o	$\sigma_o\Gamma^{-2}$	
5.8ev	~12	47R6
15	~35	47R6
21	~35	47R6
	E_n = 1Mev	
σ_t	~6.5	49B28
	Graphs Available	
σ_t	0.015-1000ev	47R6,47GIF
	0.020-1.6Mev	49B28,50Ad
	0.024-~14Mev	47GIF
References on fast n graphs and in 48WH		

116 51 65			
τ	60^m		49T11
β^+	~1.45	s	49T11
γ	~0.70	s	49T11
In-α-3n	ms, chem, f		49T11
threshold	~27		49T11

117 51 66			
τ	2.8^h		47C4
	3		39L5
K			47C4
No β^+			49T11
γ	0.156	sc	49T11
	α large		49T11
e^-	0.46	a	47C4
Sn K X-ray			47C4
In-α-2n	ms, chem, f		49T11
threshold	~18		49T11
Sn-d-n	chem		47C4,39L5
Sn-p-n	chem		47C4

118 51 67			
τ_1	5.1^h		47C4
γ	0.260	sc	49T11
	1.5	a	47C4
e^-	0.20	a	47C4
X-ray			47C4
In-α-n	ms, chem, f		49T11
threshold	~13		49T11
	chem		47C4
Sn-d-n	chem		47C4

τ_2	3.3^m		47L10
	3.9		48L2
	3.6		40R2
β^+	3.1	a	48L2
γ			48L2
In-α-n	chem		39L3
	chem, σ		40R2
Sn-p-n			44D9
	d 6^dTe		48L2

119 51 68			
τ	39^h		48L2. 47C4
K			47C4
No β^+			47C4
No γ			47C4
Sn K X-ray			48L2,47C4
Level			Te^{119}
Sn-d-n	chem		47C4
Sn-p-n	chem		47C4
Sb-d-p3n	chem		48L2
Sn^{120}-d-3n	σ		48L2
	d 4.5^dTe		48L2

120
51 69

τ_1	16.6^m		48P3
	17		37H4,39L5
	15.4		37P2
β^+	1.5	cc	38A3
Sn^{120}-d-2n	chem,σ		48L2
Sn-d-n	chem		39L5
Sb-γ-n	relσ		48W13,39B5,48P3
threshold = 9.25			49M17
Sb-n-2n			44J5,37P2
threshold = 5.5-7			38S14
Sb-d-t	chem		41K4
Sn-p-n			44D9

τ_2	6.0^d		48L2
K			48L2
γ	1.1	a	48L2
Sn K X-ray			48L2
No β^+			48L2
Sn^{120}-d-2n	chem,σ		48L2
Sb-d	chem		48L2

121
51 70

	57.25%		48W9
I	5/2	S	32B1,34C3
μ	+3.7	S	36B6,34C3
q	-0.3		49M48
	~0		40T3
Level	0.61		Te^{121}

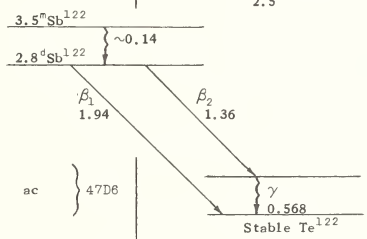
σ's

(th n,γ)2.8^dSb	6.8	47S33
(~1Mev n,γ)2.8^dSb	0.09	49H5

For other fast n values see 49B4, 48WH

122
51 71

τ_1	3.5^m		47D6
IT			
γ	~0.14	ac	47D6
Sb K_aX-ray			
3.5^mSb^{122} produced by			
Sb-n-γ			47D6
2.8^dSb^{122} produced by			
Sb-n-γ			39L5
σ			47S33
Sn-p-n			44D9
Sn-d-2n	chem		39L5
Sb-d-p	chem		48L2
Sb-γ-n	relσ		48W13



τ_2	2.8^d		39L11
	2.63		40M4
	2.5		35A1
β_1^-	1.94	s	46M6
	1.77	a	48M11
	1.76	a	40M4
β_2^-	1.36	s	46M6
	1.19	a$\beta\gamma$	48M11
	~0.81	a	40M4
γ	0.568	sc	48C5,48K4
	0.57	sc	47R1
No β^+			47B8

123
51 72

	42.75%		48W9
I	7/2	S	32B1,34C3
μ	+2.8	S	36B6,34C3
q	-1.2		49M48
Levels	0.15		Sn^{123}
	0.39		

σ's

(th n,γ)1.3^mSb	~0.03	47D6
(th n,γ)60^dSb	2.5	47S33

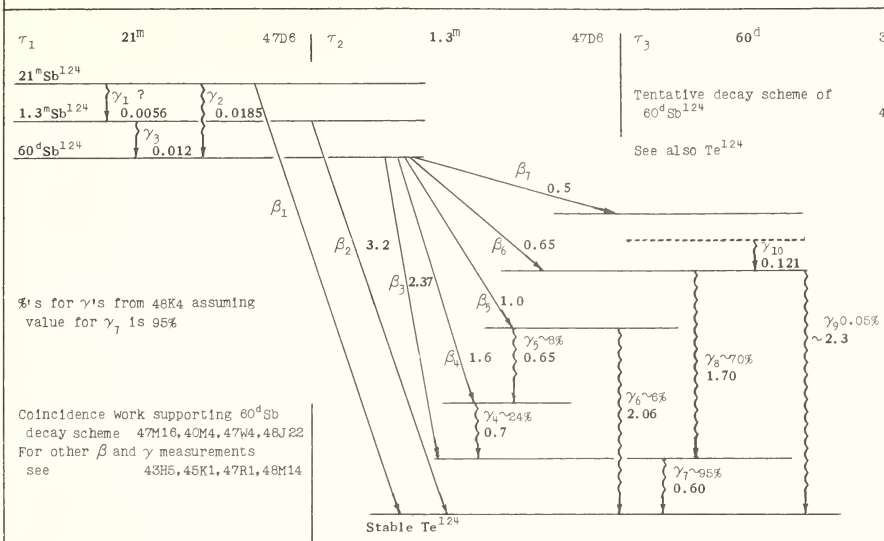
889592 O - 50 - 19

$^{124}_{51}Sb_{73}$

τ_1 21^m 47D6 | τ_2 1.3^m 47D6 | τ_3 60^d 39L5

Tentative decay scheme of $^{60d}Sb^{124}$ 48K4

See also Te^{124}



%'s for γ's from 48K4 assuming value for γ_7 is 95%

Coincidence work supporting ^{60d}Sb decay scheme 47M16,40M4,47W4,48J22
For other β and γ measurements see 43H5,45K1,47R1,48M14

β's

$^{21m}Sb^{124}$				
β_1^-				49G8
$^{1.3m}Sb^{124}$				
β_2^-		3.2		49G8
$^{60d}Sb^{124}$				
β_3^-	21%	2.37	s	48K4,48C5
	~50%	2.24	s	47M16,48F5
β_4^-	8%	1.62	s	48K4
	7%	1.50	s	48C5
β_5^-	9%	1.0	s	48K4
	7%	0.98	s	48C5
β_6^-	44%	0.65	s	48K4
	26%	0.68	s	48C5
	~50%	0.57	s	47M16,48F5
β_7^-	18%	0.48	s	48K4
	39%	0.50	s	48C5

$^{21m}Sb^{124}$ produced by
Sb^{123}-n-γ chem,σ 47D6

γ's

$^{21m}Sb^{124}$				
γ_1 ?		0.0056	pc	49G8
γ_2		0.0185	pc	49G8
		α~∞		49G8
$^{1.3m}Sb^{124}$				
γ_3		0.012	pc	49G8
		α~∞		49G8
$^{60d}Sb^{124}$				
γ_4	12%**	0.714	s	48K4
		0.732	s	48C5
		0.817	s	48I7
γ_5	4%**	0.650	s	48K4
		0.654	s	48C5
		0.645	s	48I7
γ_6	3%**	2.056	s	48K4
		2.04	s	48C5
		2.07	s	48I7

$^{1.3m}Sb^{124}$ produced by
Sb^{123}-n-γ 47D6

$^{60d}Sb^{124}$ (continued)				
γ_7	46%**	0.603	s	48K4
		α~0.002		48K4
		0.608	s	48C5
	~100%*	0.60	s	48F5
		0.598	s	48I7
γ_8	35%**	1.708	s	48K4,48C5
	~50%*	1.69	s	48F5
		1.67	s	48I7
		produces Be photo n's		47W1, 47H15,4607,42K1
γ_9	0.05%*	2.2-2.5	γn	49M8
γ_{10}		0.121	sc	48C5

* % of disintegrations
** % of γ's

^{60d}Sb produced by

Sb-n-γ	chem	39L5
	σ	47S33
Sb-d-p	chem	45K1,43H5,39L5
In-n-α	chem	39L5
Sn-d-2n	chem	39L5
Te-d-α	chem	38T2

125
51 74

τ			$\sim 2.7^{y}$ 50l6
β_1^-	0.621	s	49K14
$\sim 35\%$	0.7	a	50s14
	0.704	a	49M30
β_2^-	0.288	s	49K14
$\sim 65\%$	0.3	a	50s14
$\beta_1/\beta_2 \sim 1/2$			49K14
Probably lower energy β's			49K14
γ very weak	0.125	sc	49K14
strong	0.174	sc,s	49K14
strong	0.431	sc,s	49K14
weak	0.466	s	49K14
strong	0.609	sc,s	49K14
weak	0.646	s	49K14
Fission	chem		50c1
Sn-n	chem		49K14,49M30
Sn-d-n	chem		39L5

No $\beta\gamma$ coincidences for $E_\beta > 0.3$ 49J3

β^- of 0.7 in coincidence with γ of 0.3 49M30

Levels 0.33 Sn^{125}
?

d 10^{d}Sn 49N1
d 10^{m}Sn 49K14,50c1
p 58^{d}Te 48F2

126
51 75

τ	60^{m}		42N3
β^- 60%	0.7	a	50s16
40%	2.7	a	50s16
γ	1.2	a	50s16
Any of these radiations may be due to $70^{m}Sn^{126}$			50s16
Fission	chem		42N3

d 70^{m}Sn 42N3

127
51 76

τ	93^{h}		50s17
	95		46G6
	80		39A2
β^-	1.2	a	50s17
	0.8	a	46G6
γ	0.72	a	50s17
Fission	chem		39A2,46G6

p (84%) 9.3^{h}Te 48B19
p (16%) 90^{d}Te 48B19

129
51 78

τ	4.2^{h}		39A2
Fission	chem		39A2

p 72^{m}Te 39A2

		132 51 81
		τ ~5^m 39A2 Fission chem 39A2 p 77^hTe 39A2
133 51 82	**134** 51 83	**??**
Sb parent, if any, of 21^hI has $\tau < 10^m$ 39A2	Sb parent, if any, of 51^mI has $\tau < 10^m$ 39A2	τ 28^d 46G6 β^- 1.86 a 46G6 Fission chem 46G6

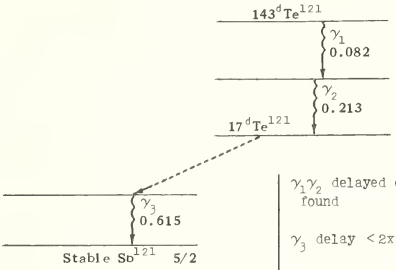
Neutron Cross Sections for Natural Element						?		
	E_n = 0.025ev					τ	2.5^h	48L2
σ_a	4.53	49P3						
	5.87	49H2						
σ_s	5.3	37G1				β^+		48L4
	Resonance					e^-		48L2
E_o	> 300 ev	49H16						
						Sb-d	chem	48L2

118 52 66			119 52 67			120 52 68		
τ	6.0^d	48L2	τ	4.5^d	48L2		0.090%	49H3
							0.091	48W9
							0.09	46W8
X-ray		48L2	γ	1.5 a	48L2			
			e^-	0.2	48L2			
				0.5	48L2			
Sb-d-5n	chem	48L2	Sb-d-4n	chem	48L2			
	p 3.3^mSb	48L2		p 39^hSb	48L2			

$^{121}_{52}$ 69

τ_1 143^d 46E3
125 40S1

τ_2 17^d 46E3
~16 46B6



$\gamma_1\gamma_2$ delayed coincidences not found 49G8

γ_3 delay $< 2\times10^{-8}$ s 46B8

143^{d}Te^{121} produced by

Sb-d-2n	chem	45Y1, 4202, 40S1
Sb-p-n	chem	40S1
Sn-α-n	chem	40S1

17^{d}Te^{121} produced by

Sb-d-2n	chem	46B6, 46E3
Sb-p-n	chem	46E3

143^{d}Te^{121}

γ_1 0.082 sc 42K2, 49H25
α large 49H25
K/L ~0.8 49H25

γ_2 0.213 sc 49H25
α_K ~0.13, K/L=4.2 49H25
0.211 sc 42K2
0.225 a 46B6, 46B8

γ weak 0.032[5], 0.035 } 49H25
these γ's not yet assigned

Te K X-ray 46E3

Xγ and e⁻γ coincidences 46B6

17^{d}Te^{121}

γ_3 0.615 sc 42K2
0.61 a 46E3
α small 46E3

Sb K X-ray 46E3

$^{122}_{52}$ 70

2.47% 49H3
2.49 48W9
2.43 46W8

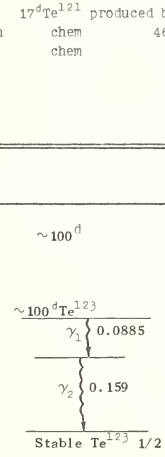
Level 0.57 Sb^{122}

σ's
(th n,γ) ~100^{d}Te ~1 49H25

$^{123}_{52}$ 71

τ ~100^d 49H25

IT 49H25



γ_1 0.0885 sc 49H25
K/L = 0.92 49H25
0.0883 sc 42K2

γ_2 0.159 sc 49H25
α_K ~0.2, K/L = 7.7 49H25
0.157 sc 42K2

Te^{122}-n-γ 49H25

0.89% 49H3, 48W9
0.85 46W8

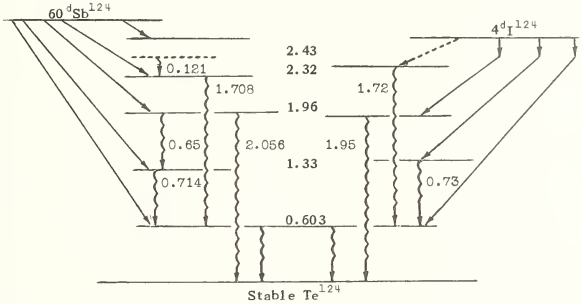
I 1/2 S 49M47

μ $\frac{\mu(Te^{123})}{\mu(Te^{125})} = 1.208$ 49M47

124
52 72

4.74%		49H3
4.63		48W9
4.59		46W8

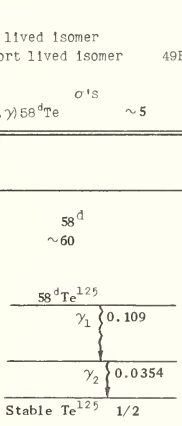
Level scheme 49M35



Short lived isomer		47H24
No short lived isomer		49B9, 49M26
σ's		
(th n, γ) 58 d Te	~5	49H25

125
52 73

τ	58 d		49H27
	~60		48F2
IT			48F2



γ_1	0.109	sc	49H27
	$\alpha \sim 1$, K/L = 1.5, L/M ~ 3.5		49H25, 49H27
	0.110	sc	49K14
	K/L = 1.2		49K14
γ_2	0.0354		49H25
	$\alpha_K \sim 3$, $\alpha_L \sim 0.41$		49B49
$\gamma_1\gamma_2$ in cascade			49B49
γ_2 delay < 5x10^{-8} s			49B49
Te^{124}-n-γ σ			49H25
d 2.7 y Sb			48F2, 49H27

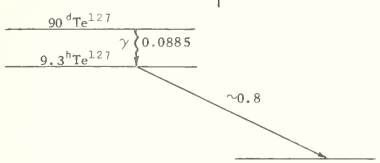
	7.03%		49H3
	7.01		48W9
	6.98		46W8
I	1/2	S	49F8
μ	$\frac{\mu(Te^{123})}{\mu(Te^{125})} = 1.208$		49M47
Levels			Sb^{125}

126
52 74

18.72%		49H3, 48W9
18.70		46W8
σ's		
(th n, γ) 9.3 h Te	0.8	47S33
(th n, γ) 90 d Te	0.07	47S33

127
52 75

τ_1	90^d	40S1	τ_2	9.3^h	40S1
IT		40S1			



γ	0.0885 sc	49H25	β^-	~0.8	a	40S1
	K/L = 0.75	49H25		0.70	a	46PP
	0.085 sc	41H1				
	$\alpha \sim \infty$, K/L = 0.75	41H1				
	$\alpha \geqslant 5.7$	48W18	No γ			46PP
Te^{126}-n-γ		49H25	Te-n-γ	chem		40S1
Te-n-γ	chem	40S1		σ		47S33
	σ	47S33	I-n-p	chem		40S1
Te-d-p	chem	40S1	Te-n-2n			38T2
I-n-p	chem	40S1	Fission	chem		39A2
Fission	chem	39A2	Te-d-p	chem		40S1
d (16%) 93^hSb		48B19,39A2	d (84%) 93^hSb			48B19,39A2

128
52 76

	31.75%	49H3
	31.78	48W9
	31.85	46W8
τ for double β decay > 1.3×10^{19} y		49I3

σ's

(th n,γ) 72^mTe	0.133	47S33
(th n,γ) 32^dTe	0.015	47S33

129
52 77

τ_1	32^d	40S1	τ_2	72^m		40S1
	35.5	48W13		70		39A2
				67.3		48W13
IT		40S1	β^-	1.8	s	47R1
				1.75	a	46PP
γ	0.106 sc	49H25		1.6	a	50n5
	K/L = 1	49H25				
	$\alpha \geqslant 1.9$	48W18	γ	0.3	a	46PP
	0.102 sc	41H1		~0.8	a	46PP
	$\alpha \sim \infty$, K/L ~ 1	41H1				
			Fission	chem		39A2
			Te-γ-n			39B5
				relσ		48W13
Fission	chem	50n5	Te-n-γ	chem		40S1
Te-γ-n	relσ	48W13		σ		47S33
Te-n-γ	chem	40S1	Te-n-2n			37H4,38T2
	σ	47S33	Te-d-p	chem		40S1
Te-d-p	chem	40S1				
Te-n-2n		38T2	d 4.2^hSb			39A2

130
52 78

	34.27%	49H3
	34.46	48W9
	34.51	46W8
τ for double β decay > 8.0×10^{19} y		49I3

σ's

(th n,γ) 1.25^dTe	<0.008	47S33
(th n,γ) 25^mTe	0.22	47S33

131
52 79

τ_1	1.25^d		39A2
	1.2		40S1
IT			40S1
γ	0.177	sc	41H1
	$\alpha \sim 0.6$		41H1
	$\alpha \geqslant 0.6$		48W18
	K/L = 2		41H1, 49H25
Te-n-γ	chem		40S1
	σ		47S33
Te-d-p	chem		40S1
Fission	chem		39A2

τ_2	25^m		40S1
	30		39A2
β^-	> 1.8	a	48W18
Te-n-γ	chem		40S1
	σ		47S33
Te-d-p	chem		40S1
Fission	chem		39A2
	p 8^dI		39A2, 40S1

132
52 80

τ	77^h		39A2
	66		39H8
β^-	0.28	a	50n6
	~0.3		43B2
γ	0.22	a	50n6
Fission	chem		39A2, 48SP
Mass assignment from range of fission fragment			48K9
	d ~ 5^mSb		39A2
	p 2.4^hI		39A2, 39H7

133
52 81

τ	60^m		39A2, 45W5
β^-			39A2
Fission	chem		39A2
Mass assignment from range of fission fragment			48K9
	p 21^hI		39A2, 39H7

134
52 82

τ	43^m		39A2
Fission	chem		39A2
Mass assignment from range of fission fragment			48K9
	p 52^mI		39H7, 39A2, 40P3

135
52 83

Te parent, if any, of 6.68^hI has

τ	$< 1^m$		40D7
	< 2		50g9, 50k6

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?		
τ ~1^{m} 43H8 Fission chem 43H8		

Neutron Cross Sections for Natural Element						119 ? 53 66 ?		
σ_s coh	3.4	49S12	Graphs Available			τ	30^m	49M53
σ_s bound	3.8	49S12	σ_t	0.01-1000ev	47GIF,47W8,47J4			
			See also		49H16			
				0.020-1.6Mev	49B28,50Ad			
	E_n = 0.025ev			0.02-3.5Mev	47GIF	β^+	4.0	49M53
σ_a	6.1	49P3	Other references on graphs and in		48WH			
	9.1	49H2						
σ_t	11	47W8						
	10.3	47J4						
	Resonances							
E_o	$\sigma_o \Gamma^2$							
20.6ev	~4	47W8						
20.3		47J4						
32	~135	47W8						
42	~135	47W8						
Two additional resonances between 25 and 50ev		47J4				Sb-α	chem	49M53
						E_α > 100Mev		
	E_n = 2.5Mev							
σ_t	5.4	39A5						
						p several days Te		49M53

120 53 67	121 53 68			122 53 69		
	τ	1.8^h	49M53	τ	4^m	49M53
	β^+	1.2	49M53	β^+	2.9	49M53
	e^-	0.185	49M53			
	Sb-α	chem	49M53	Sb-α-3n	chem	49M53
	E_α > 45Mev					
	p 17^dTe		49M53			

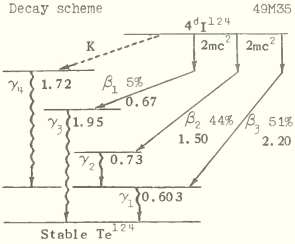
123
53 70

τ	13^h		49M35, 49M53
K or IT			49M35
γ	0.159	sc	49M35
	See also		Te^{123}
	~0.18	ac	49M53
Sb^{121}-α-2n	chem		49M35
Sb-α-2n	chem, f		49M53
Not produced by			
I-fast n's			49M35

124
53 71

τ	4^d		38L5, 44D9
	4.5		49M53

Decay scheme 49M35



β_1^+ 5%	0.67	s	49M35
β_2^+ 44%	1.50	s	49M35
β_3^+ 51%	2.20	s	49M35
Spectral shape consistent with $\Delta I=2$, yes			49M35
	2.1		49M53
γ_1	0.603	sc	49M35
γ_2	0.73	s	49M35
γ_3	1.95	s	49M35
γ_4	1.72	s	49M35

Te X-ray
$\beta\gamma$, $\gamma\gamma$ coincidences } 49M32
No β^- coincidences

Sb-α-n	chem	49M35
	chem, yield	38L5
Sb^{121}-α-n	chem, f	49M53
Sb-α-3n	chem, f	49M53
Te-p-n		44D9

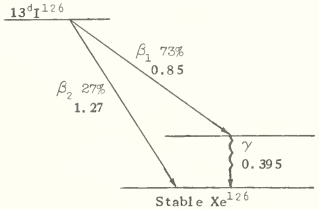
See also Te^{124}

125
53 72

τ	$\sim 56^d$		46R4
K			47G5, 46R4
Te K_α X-ray			47G5
Sb-α-2n	chem, f		49M53
Te-d	chem, yield		47G5
	chem		46R4

126
53 73

τ	13.0^d		38L5
	13.1		48M33



β_1^- 73%	0.85	s	49M35
β_2^- 27%	1.27	s	49M35
	1.1	a	38L5
γ	0.395	sc, s	49M35
	0.5	a	38L5

I-γ-n		48M33
	rel yield	49P5
	threshold = 9.3	49M17
	9.45	49B3
Sb-α-n	chem, yield	38L5
	chem, f	49M53
Te-d-n	chem	38L5
Te-p-n		44D9
I-n-2n		38L5

127
53 74

	100%		37N2
I	5/2	S	39T3, 38M6
μ	2.7944		49Po
		I	49Z2, 48P9
		S	39S15
		Mic	49G19
q	-0.75	Mic	48B23, 48S31, 48G21, 48T11
	-0.46	S	39M7, 39T3, 39S16

σ's

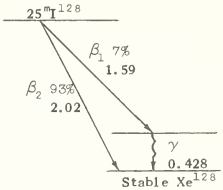
(th n,γ)25^mI	6.3	47S33
(1Mev n,γ)25^mI	0.11	49H5
Other fast n values		49B4, 48WH

Graphs Available

σ(n,γ)25^mI 0.03-6Mev		46M19, 47GIF, 50Ad

128
53 75

τ	24.99^m		41H4



β_1^- 7%	1.59	s	46S10
β_2^- 93%	2.02	s	46S10
	2.2	a	38L5
γ	0.428		46S10
I-n-γ	σ		47S33
	f		47J4
E_γ(max) =	7.0		49K15
Te-d-2n	chem, yield		38L5
Te-p-n			44D9

129
53 76

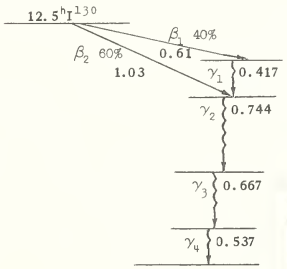
τ	$2\text{-}4\times10^7$ y		49P19
	long		47K4, 50L7
I	7/2	Mic	49L9
μ	2.72	Mic	49G19 (49Po)
q	-0.43	Mic	49L9 (49Po)
β^-	~0.12		49P19
γ or X-ray	~0.03		49P19
β/γ ~ 1			49P19
Levels	0.3		Te^{129}
	~0.8		

σ's

(th n,γ)	~15	49P19
(th n,γ) 12.5^hI	~8	47K4
Fission	chem	47K4

130
53 77

τ	12.5^h	39T2
	12.6	38L5



β_1^- 40%	0.61	s	43R2
β_2^- 60%	1.03	s	43R2
γ_1	0.417	sc	43R2
	$\alpha_K = 12\times10^{-3}$		
γ_2	0.744	sc	43R2
	$\alpha_K = 3\times10^{-3}$		
γ_3	0.667	sc	43R2
	$\alpha_K = 4\times10^{-3}$		
γ_4	0.537	sc	43R2
	$\alpha_K = 7\times10^{-3}$		

I-n-γ	chem, σ	47K4
Cs-n-α	chem	40W5
Te-d-2n	chem, yield	38L5

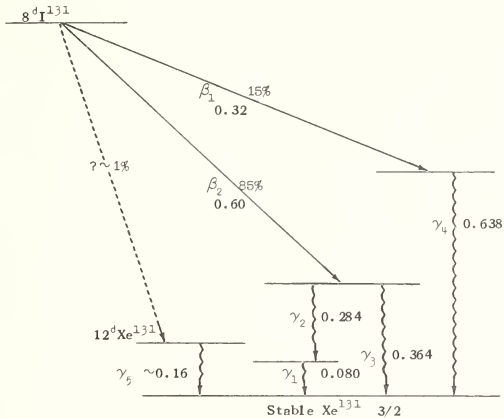
Order of $\gamma_2, \gamma_3, \gamma_4$ unknown. See Cs^{130}

$\beta\gamma$ and $\gamma\gamma$ coincidence rates support decay scheme 43R2

$\alpha_L \ll \alpha_K$ for all γ's 43R2

$^{131}_{53}$ ^{78}

τ	8.0^d	47S28, 38L5, 50k9
	8.1	46G6



Decay scheme 48M28

About 1% of I^{131} decays to $12^d Xe$. Very weak γ's of ~0.165 probably due to Xe daughter 49B6

		σ's	
(th n, γ) $2.4^h I$		~600	49Y4
Te-d-n	chem, yield		38L5
	chem		39T2
Fission	chem		39A2, 40S1, 39H7, 46G6
	d $25^m Te$		39A2, 40S1
	p (1%) $12^d Xe$		49B6

β_1^-	15%	0.32	s	48M28
	20%	0.31	s	49F1
		0.25	s	49K14
β_2^-	85%	0.600	s	48M28
	80%	0.600	s	49F1
		0.605	s	49K14
		0.60	a	50k9
γ_1		0.080133	s cryst	49L11
	~8%*	0.080	sc	48M28
		α = 0.8, K/L = 5.5		48M28
		0.078	sc	49F1
		α = 0.7		49F1
		0.080	sc	49K14
		α = 0.2, K/L = 8.4		49K14
		0.0801	sc	49C13
γ_2		0.2841	s cryst	49L11
	8%*	0.283	sc	48M28
		α = 0.05, K/L > 2		48M28
	9%*	0.284	sc	49F1
		α ~ 0.05		49F1
		0.282	sc	49K14
		α = 0.08		49K14
		0.2841	sc	49C13
		0.284	sc	49M33
γ_3		0.3642	s cryst	49L11
	100%*	0.363	sc	48M28
		α = 0.02, K/L = 5.2		48M28
	100%*	0.364	sc	49F1
		α = 0.02		49F1
		0.363	sc	49K14
		α = 0.2, K/L = 4		49K14
		0.3642	sc	49C13
		0.364	sc	49M33
γ_4	20%*	0.638	s	48M28
		α < 0.005		48M28
	13%*	0.640	s	49F1
		0.637	s	49K14
		0.625	s	49C13
		0.638	s	49M33
γ_5	weak	~0.159	sc	49M33
		~0.163	sc	49K14
		0.164	sc	49C13
		~0.165	a	49B6
		α ~ 20		49B6
Other weak γ's				
		~0.208	sc	49M33
		0.177	sc	49C13

$\beta\gamma$ and βe^- coincidences 48M28

* relative values

132
53 79

τ		2.4^h		39A2
		2.3		39H8
β^-	~50%	0.9	a	50n6
		~1.35	a	43B2
	~50%	2.2	a	50n6
γ	~50%	0.6	a	50n6
		0.85	a	43B2
	~50%	1.4	a	50n6
Level		0.22		Te^{132}
Fission		chem		39A2, 39H7, 46G6, 48SP
		d 77^hTe		39A2, 39H7

133
53 80

τ		21^h		49B47
		22		39A2, 40W5, 50k6
β^-	6%	~0.5	ac	49B47
	94%	1.4	ac	49B47
		1.4	a	50s19
γ	94%*	0.53	s	49B47
		0.528	s	47P13
	5%*	~0.85	s	49B47
	1%*	~1.4	s	49B47

* % of disintegrations

$\gamma\gamma$ coincidences in ~5% of disintegrations 49B47

No evidence for metastable state with $\tau > 10^{-6\,s}$ 49B47

Fission	chem		39A2, 39H7, 40W5
	d 60^mTe		39A2, 39H7
	p 5.3^dXe		45W5

134 ?
53 81 ?

τ		50.8^m		49L19
		54		39A2
β^-		~1.6	a	49L19
		~3.9	a	49L19
γ		>2.3		49L19
Fission		chem		39A2, 39H7, 48SP
		d 43^mTe		39A2, 39H7, 40P3

135
53 82

τ		6.68^h		47P13
		6.7		50g9, 50k6
		6.6		41S2, 40D7
β^-	35%	0.47	s	47P13
	40%	1.0	s	47P13
	25%	1.4	s	47P13
		1.4	a	50k6
		1.55	a	50s32
γ		1.27	s	47P13
		1.3	a	50s32
		1.8	s	47P13
		1.6	a	50k6
	1.1%*	2.4	γn	49L19

1.4 β not in coincidence with γ 47P13

* % of disintegrations

Fission	chem		41S2, 40W5, 48SP, 50k6
	p (~10%)	15.3^mXe	40G2, 45W5, 50g9
	p (~30%)	15.3^mXe	47P13
	p (~90%)	9.2^hXe	45W5, 40G2, 50g9
	p (~70%)	9.2^hXe	47P13

136
53 83

τ		86^s		49S27
		108		40S3
β^-		6.5	a	49S27
γ		2.9	a	49S27
Fission		chem		40S3

137 53 84	138 53 85	139 53 86
τ 19.3^{s} 49S14 22 48H33 22.5 47R2 30 40S3	τ 5.9^{s} 49S14	τ 2.7^{s} 49S14
β^- 47S7, 48H33	β^- 49S14	β^- 49S14
Delayed n emitter 47S7		
$\bar{E}_n$ 0.56 a 48H33 0.7 46B22		
Delayed n's in ~7% of disintegrations 50I2		
Fission chem 47R2, 41S3, 43S1, 47S7	Fission chem 49S14	Fission chem 49S14
p 3.9^{m}Xe 49T4, 43S1, 49S14	p 33^{m}Cs 49T4, 49S14	p 85^{m}Ba 49S14
No I found in fission with $\tau > 8^{d}$ except I^{129} 50I7		

Neutron Cross Sections for Natural Element			124 (54 70)		125 (54 71)
	$E_n = \sim 0.025$ev		0.095%	47L2	
σ_t	37	42R3	0.102	47D9	
			0.094	37N2	
σ_s	4.0	50H5			

126 (54 72)			127 (54 73)				
	0.088%	47L2,37N2	τ_1	75^s		40C6	τ_2 34^d 40C6
	0.098	47D9					
			IT			40C6	γ 0.9 ac 40C6
			γ	0.125	sc	40C6	Xe or I X-ray 40C6
				0.175	sc	40C6	
			Xe K X-ray			40C6	
Level	0.395	I^{126}					
			I-p-n	chem		40C6	I-p-n 40C6
							Xe-n-γ 44C11
							I-d-2n 42C3
							d 5.5^hCs 49F9
			Genetic relationship between 75^s and 34^d activities not shown				40C6

* "chem" on the Xenon pages indicates separation which was carried out by physical means

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128
54 74

	1.917%	47L2
	1.93	47D9
	1.90	37N2
Level	0.43	I^{128}

129
54 75

	26.24%		47L2
	26.51		47D9
	26.23		37N2
I	1/2	S	34K2,34J1
μ	-0.9	S	34K2,34J1
Level	~0.5		Cs^{129}

130
54 76

	4.053%		47L2
	3.68		47D9
	4.07		37N2
Levels	0.51	?	Cs^{130}
	0.537	?	I^{130}
	1.20	?	I^{130}
	1.95		I^{130}
	2.37		I^{130}

131
54 77

τ	~12^d		49B6
	~14		47A4
	11		44C11
IT			49B6,44C11
γ	~0.165	a	49B6
	α~20		49B6
Xe K X-ray			49B6
Fission	chem		47A4
Xe-n-n			44C11
	d (~1%) 8^{d}I		49B6

	21.24%		47L2
	21.04		47D9
	21.17		37N2
I	3/2	S	34K2,34J1
μ	+0.8	S	34K2,34J1
q	~0		38S10
Levels	0.080	?	I^{131}
	0.145	?	Cs^{131}
	~0.16		12^{d}Xe^{131}
	0.364		I^{131}
	0.638		I^{131}

132
54 78

	26.93%		47L2
	27.12		47D9
	26.96		37N2
Levels	0.6		I^{132},Cs^{132}
	1.4	?	I^{132}
	σ's		
(th n,γ)5.3^{d}Xe	0.2		43K5

*"chem" on the Xenon pages indicates separation which was carried out by physical means

133 (54 79)

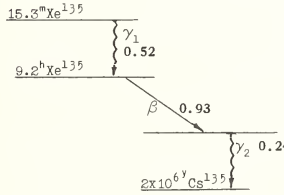
τ	5.271^d		49M25
	5.3		50e5
	5.4		41C2
β^-	0.315	s	49T4
	0.34	a	50e5
	0.26	a	45W5
	0.32	a	43S2,43B2
γ	0.085	a	50e6
	0.083	a	43B2
X-ray	0.031	a	50e6
	0.040	a	50e5
Fission	ms		49T4,49M25
Cs-n-p	chem		45W5,44C11,45S2
Ba-n-α	chem		45W5,44C11
Xe-n-2n			43R1
Xe-n-γ			43R1,44C11
Te-α-n	chem		41C2
Xe-d-p	chem		41C2
	d 21^hI		45W5

134 (54 80)

	10.52%		47L2
	10.54		47D9,37N2
Level	>2.3		I^{134} ?
	σ's		
(th n,γ)9.2^hXe	0.2		44T3

135 (54 81)

τ_1	15.3^m		48B16
	15.6		43R1
	13		50n9
	10		40G2,45W5



γ_1	0.52	s	47P13
	0.54	ac	50n9
	~0.5	a	45W5
	0.6	ac	43S2
Fission	chem		40G2,45W5
Xe-n-γ			46R7,43R1
Xe-n-2n			43R1
	d (~10%) 6.7^hI		45W5,40G2, 50g9
	d (~30%) 6.7^hI		47P13
τ_2	9.2^h		50n7,50g9
	9.4		40W5
	9.5		40D7
	9.6		43R1,41C2
β^-	0.93	s	49T4,47P13
	0.95	a	43B2
	0.9	a	45W5
	1.0	a	50h4
γ_2	0.247	s	47P13
	0.25	a	45W9
	0.26	a	50n7
Levels	?		I^{135}
Fission	ms		49T4
	chem		40D7,45W5
Xe-d-p	chem		41C2
Ba-n-α	chem		45W5,43S2
Xe-n-γ			43R1
	σ		44T3
Xe-n-2n			43R1
	d (~90%) 6.7^hI		45W5,40G2, 50g9
	d (~70%) 6.7^hI		47P13
	p $2x10^6{}^y$Cs		45W5,50f5,50e7

136 (54 82)

	8.93%		47L2
	8.98		47D9
	8.95		37N2
Levels	~1		Cs^{136}
	2.9		I^{136}
	σ's		
(th n,$\gamma\beta$)37^yCs	0.15		44T3
(~1Mev n,γ)3.9^mXe	0.001		49H28

* "chem" on the Xenon pages indicates separation which was carried out by physical means

137 54 83			138 54 84			139 54 85		
τ	3.9^m	48S16	τ	17^m	40G5	τ	41^s	50d1
	3.8	43S1					~30	40H4
	3.4	43R1						
β^-	~4 a	43B2	β^-		39H7	β^-		39H7
Neutrons emitted following 19^s I disintegration		I^{137}						
Fission	ms	49T4	Fission	ms	49T4			
	chem	43S1		chem	40H4,40G5,	Fission	chem	40H5,40H4
Xe-n-γ		43R1,48S16			43S2,46PP			
	d 19^s I	49S14,						
		43S1,49T4					p 85^mBa	50d1,39H3
	p 37^yCs	50t1,50g16		p 33^mCs	40H4,40G5,43S2		p 9.5^mCs	39H3,40H4

140 54 86			141 54 87			142 54 88
τ	16^s	50d1,46D14	τ	3^s	50d1	
	$<0.5^m$	40H4		1.7	50o1	
β^-		40H4	β^-		50b2	
Fission	chem	40H4,46PP	Fission	chem	50b2	
				p short Cs	50b2,50d1	
	p 12.8^dBa	40H4,50o1,		p 3.7^hLa	50b2	
		50d1,50b2		p 28^dCe	50o1,50d1	

* "chem" on the Xenon pages indicates separation which was carried out by physical means

143 54 89	144 54 90	145 54 91
τ ~1^{s} 50d1	τ ~1^{s} 50d1	τ 0.8^{s} 50d1
Fission chem 50b2	Fission chem 50d2	Fission chem 50d1
p 33^{h}Ce 50b2,50d1 p 13.8^{d}Pr 50o1	p 275^{d}Ce 50d2	p 1.8^{h}Ce 50d1
??		
τ 68^{m} 41C2	No Xe with τ >5^{d} found in fission 50h1	
Xe-d-p 41C2		

* "chem" on the Xenon pages indicates separation which was carried out by physical means

Neutron Cross Sections for Natural Element				127 (55 72)				128 (55 73)
	$E_n = 0.025$ev			τ	5.5^h		49F9	
σ_a	29		49P3					
σ_t	~50		42L1	β^+	~1.2	a	49F9	
				e^- ?	0.35	a	49F9	
				No γ's harder than annihilation γ's			49F9	
				X-ray			49F9	
				I-α-4n	ms, chem		49F9	
					p 34^dXe		49F9	

129 (55 74)				130 (55 75)				131 (55 76)			
τ	31^h		49F9	τ	30^m		49F9,48R4	τ	9.6^d		49Y1
									10		47Y1
									10.2		50K12,47K5
No β^+			49F9	γ	0.51		49F9	K			50K12,47K5,47Y1
γ	~0.5		49F9					No β^+			50f7,47F9
e^-	0.33	a	49F9	X-ray			49F9	No γ			50K12,47K5
K,L X-rays			49F9					γ	0.145	a,ac	47Y1
									α~32		47Y1
								e^-	0.115		49Y1
								Xe K X-ray			47Y1,49Y1,47K5, 50K12,47F9
								Levels	0.26, 0.5, ~1.2 } ?		Ba^{131}
I-α-2n	ms, chem		49F9	I-α-n			49F9,48R4				
								Ba-n-$\gamma\beta$	ms		49K7
									d 12^dBa		50K12,47K5,47Y1

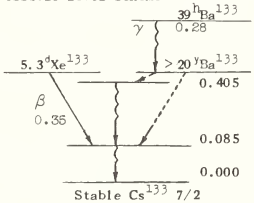
132
55 77

τ	7.1^{d}		44C11
K			44C11
γ	0.62	a	44C11
e^{-}	0.6	a	44C11
Cs-n-2n			44C11

133
55 78

	100%		37N2
I	7/2	S	37F3,34J2,31K1
		Z	34C4
μ	2.563		49Po
		I	49B7,49C2
		M	39K10
q	$\leqslant 0.3$		40S9

Possible level scheme

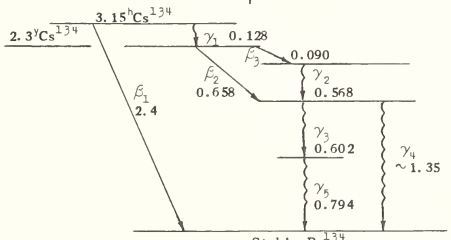


σ's

(th n,γ) 3^{h}Cs	0.016	47S33
(th n,γ) 2.3^{y}Cs	26	47S33
(30Mev α,2n) 19^{h}La	0.03	48C3

134
55 79

τ_1	3.15^{h}		45S2
	3		40K7
τ_2	2.3^{y}		50g19
	1.7		40K7
	$>254^{d}$		45S2



$3.15^{h}Cs^{134}$ produced by

Ce-n-γ	chem,σ		40K7
Cs-d-p	chem		40K7

$2.3^{y}Cs^{134}$ produced by

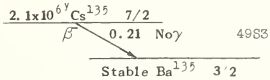
Ce-n-γ	chem,σ		40K7,38S6
Cs-d-p	chem		40K7
Ba-d-α			43H10

Order of γ's uncertain	48S1,47E2
$\gamma\gamma$ coincidences	48S1
γ 1.63 $\leqslant$E $\leqslant$2.3 in 7×10^{-5}% of disintegrations	49F5
No Xe K X-ray	48S1
$\gamma\gamma$ angular correlation indicates I = 4,2,0	48B18
* relative % of γ's	47E2

$3.15^{h}Cs^{134}$				
β_1^-		2.4	a	45S2
γ_1		0.128	s	49C1
		0.15	s	47P10
		0.16	a	47M21
γ ?		0.7	a	45S2
$2.3^{y}Cs^{134}$				
β_2^-	75%	0.658	s	47E2
	95%	0.65	s	47S13
		0.635	s	47P10
β_3^-	34%	0.090	a,$\beta\gamma$	49M36
	25%	0.09	s	47E2
γ_2	26%*	0.568	s	47E2
		0.566	s	48S1
γ_3	100%*	0.602	s	47E2
		0.603	s	48S1
		0.610	s	47P10
γ_4		~1.35	s	48S1
γ_5	100%*	0.794	s	47E2
		0.798	s	48S1
		0.799	s	47P10

135
55 80

τ	2.1×10^{6} y		49S3
	5×10^{6}		49B5
I	7/2	M	49D1
μ	2.72	M	49D1



49S3

Level in Cs^{135} 0.25 Xe^{135}

σ's

(th n,γ) 13.7^{d}Cs ~15 49S3

Fission chem 49S3

d 9.2^{h}Xe 50e7, 50f5, 49S3, 45W5

136
55 81

τ	13.7^{d}		48G11
	13		50g13, 50f6
	10.2		44C11
β^-	~0.35	a	48G11
	~0.28	a	50f6
γ	0.9	a	48G11
	1.2	a	50f6
γ/β = 2			48G11
$\beta\gamma$ coincidences			50f6

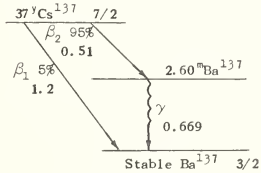
Fission chem 50f6, 48SP

La-n-α chem 48G11, 44C11

137
55 82

τ	37^{y}		48E5
	33		50g17
I	7/2	M	49D1
μ	2.84	M	49D1

Proposed decay scheme 49P2



Ba X-ray in 2.60^{m} activity 48T3

Fission ms, chem 46H5
chem 48SP, 46PP

d 3.9^{m}Xe 50t1, 50g16

β_1^-	5%	1.2	s	49P2
	<5%	1.2	s	49O3
	unallowed shape?			49O3, 49P2
β_2^-		0.51	s	49L6
	95%	0.521	s	49P2
		0.518	s	49O3
	100%	0.55	s	48T2
		0.57	a	48E5
	spectral shape indicates ΔI=2, yes			49O3, 49L6, 49P2
γ		0.669	sc	49P2
		0.663	sc	49O3, 48T2
		α = 0.12		48T2
		α_K = 0.08, K/L = 5.0		49O3
		0.12, K/L = 4.8		49M1
		2.60^{m} delay		Ba^{137}

138
55 83

τ	33^{m}		50e8, 40H4
	32		50g16
β^-	2.68	s	49T4
	2.65	a	40G5 (46B27)
γ	1.2	a	50g16

Fission ms 49T4
chem 39H7, 40G5, 40S5, 48SP

Ba-n-p 43S2

d 17^{m}Xe 40G5, 40H4

139 55 84			140 55 85			141 55 86		
τ	9.5^{m}	49S15	τ	66^{s}	49S15	τ	short	50b2,50o1, 50d1
	10	39A1		40	40H4			
	7	40H4						
Fission	chem	40H5,39H3	Fission	chem	39A1,40H4	Fission	chem	50b2,50d1
	d 41^{s}Xe	40H4,40H5,39H3		d 16^{s}Xe	50b2,50d1,50o1		d 3^{s}Xe	50b2,50d1
	p 85^{m}Ba	40H4,40H5,39H3		p 12.8^{d}Ba	50b2,50d1,50o1		p 28^{d}Ce	50o1,50d1
							p 3.7^{h}La	50b2

142 55 87			143 55 88			144 55 89		
τ	$\sim 1\text{-}2^{m}$	42H6	τ	short	50b2,50o1,50d1	τ	short	50d2
Fission	chem	42H6	Fission	chem	50b2	Fission	chem	50d2
				d 1^{s}Xe	50b2,50d1			
				p 13.8^{d}Pr	50o1		d short Xe	50d2
	p 6^{m}Ba	42H6		p 33^{h}Ce	50b2,50d1		p 275^{d}Ce	50d2

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$^{145}_{55}$ $_{90}$		
τ short 50d1		
Fission chem 50d1		
d 0.8^{s}Xe 50d1		
p 4.5^{h}Pr 50d1		
p 1.8^{h}Ce 50d1		

Neutron Cross Sections for Natural Element						129 56 73		
	E_n = 0.025ev							
σ_a	1.05	49P3						
	1.38	49H2						
σ_s	8	37G1						

130 56 74			131 56 75				132 56 76		
	0.101%	38N3	τ	12.0^d		50k12,47K5		0.097%	38N3
	0.103	49H38		11.7		47Y1		0.096	49H38
			K			50k12,47K5			
			No β^+>0.1			47Y1			
			No β^+			50f7,47F9			
			e^-	<0.20		47Y1			
			γ	0.26	a	50k12,47K5			
				0.22		47Y1			
			strong	0.5	a	50k12,47K5			
			strong	0.5		47Y1			
	σ's		weak	~1.2	a	50k12,47K5		σ's	
(th n,γ) 12^{d}Ba	6	47K5	weak	1.7		47Y1	(th n,γ) 20^{y}Ba	≥6	50k13,47K5
(th n,$\gamma\beta$) 10^{d}Cs	24mb	49Y1							
			Cs K X-ray			50k12,47K5			
			Ba-n-γ	ms		49K7			
				chem		47Y1,47K5			
			Ba-d-p	chem		47Y1			
			p 10^{d}Cs			50k12,47K5,47Y1			

133
56 77

τ_1	38.9^h	48Y1
	38.8	43W3
	38	48M33
IT		48Y1
γ	0.276 sc	41C3
	$\alpha = 2.45$, K/L = 3.2	
Fission	chem	49G13, 48SP
Cs-p-n		44D9
Cs-d-2n	chem	41C3
Ba-n-γ	chem	48Y1
Ba-γ-n	chem	48M33
	$p > 20^y$Ba	48Y1

τ_2	$> 20^y$	50k13, 47K5
K		50k13, 47K5
γ	0.085 a, cc	48Y1
	$\alpha = 0.34$ K/L = 10	48Y1
	0.320 a, cc	48Y1
	$\alpha = 0.02$	48Y1
	0.36 a	47K5
Cs K X-ray		47K5
See Cs^{133}		
Ba-n-γ	chem	48Y1
	σ	47K5, 50k13
Cs-d-2n	chem	48Y1
Ba-d-p		48Y1
	d 39^dBa	48Y1
	Not p active Cs	47K5, 50k13

134
56 78

	2.42%	38N3
	2.39	49H38
Levels		Cs^{134}
	0.79	
	1.40	
	1.96	

135
56 79

τ	28.7^h	48Y1
IT		48Y1
γ	0.3	49R5
e^-	0.28 a	49R5, 48Y1
Ba K X-ray		49R5, 48Y1
Ba-d-p		48Y1
Ba-n-γ		48Y1
Ba^{134}-n-γ	chem	49R5
Not produced by		
Cs-d-n, 2n		49R5
Cs-α-p		49R5

	6.59%	38N3
	6.56	49H38
I	3/2 S	37B9, 32M6, 49A10
μ	0.837	41H14
Level	0.76	La^{135}

136
56 80

	7.81%	38N3
	7.74	49H38
Levels	?	Cs^{136}

137
56 81

τ	2.60^m		49M1
	2.63		48T3
	2.5		48E5
IT			48T3
γ	0.669	sc	49P2
	0.663	sc	49O3, 48T2
	$\alpha = 0.12$		48T2
	$\alpha_K = 0.08$, K/L=5.0		49O3
	0.12, K/L=4.8		49M1
Ba K X-ray			48E5
e^-X coincidences			48T3
See Cs^{137}			
Ba-n-γ	chem		40K7
	d 37^yCs		48E5, 48T3

	11.32%		38N3
	11.25		49H38
I	3/2	S	37B9, 32M6, 49A10
μ	0.936		41H14

138
56 82

	71.66%		38N3
	71.83		49H38
Levels	0.88		La^{138}
	1.2		Cs^{138}
σ's			
(th n,γ)85^mBa	0.5		47S33
(~1Mev n,γ)85^mBa	2.6mb		49H5
Values at other energies			49B4, 48WH

139
56 83

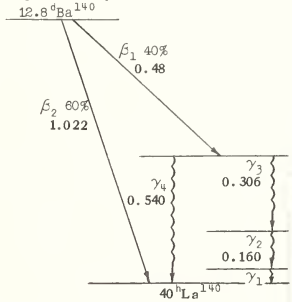
τ	85^m		50d4
	84		48S27
β^-	2.27	s	48S27
	2.2	a	50k8
γ	0.165	sc	49L14
26%*	0.163	sc	48S27
	$\alpha = 0.20$	K/L = 6	48S27
0.6%*	1.05	a	48S27

*% of disintegrations

σ's		
(th n,$\gamma\beta$)40^hLa	3.8	45K17
(pile n,$\gamma\beta$)40^hLa	4.7	49Y3
Ba-d-p	chem	37P3, 40K7
Ba-n-γ	σ	47S33
Ce-n-α		43W1
Fission	chem	50k8, 39H7, 39H3
	d 9.5^mCs	39H7, 39H3

140
56 84

τ	12.8^d		50e9, 47S25
	12.5		42G2
Proposed decay scheme			49B36



β_1^- 40%	0.48	s	49B36
	0.465	s	49L14
25%	~0.4	a	50e3
β_2^- 60%	1.022	s	49B36
	0.990	s	49L14
	1.05	s	50w5
75%	1.0	a	50e3
γ_1	0.076	not observed	
γ_2	0.160	sc	49B36
	0.160	s	49L14
γ_3	0.306	sc	49B36
	0.310	s	49L14
γ_4	0.540	sc	49B36
	0.535	s	49L14
	0.54	s	50w5
	0.52	a	50e3
$\beta\gamma$ coincidences			49M13
Fission	ms		48H25
	chem		39H7, 42H6, 46PP, 48SP
	d 66^sCs		42H6, 50b2, 50d1, 50d2, 50o1
	p 40^hLa		39H4, 46PP

141 56 85			142 56 86			143 56 87		
τ	18^m	42H6,50g12	τ	6^m	42H6	τ	$<0.5^m$	42H6
β^-	~2.8	48L10						
γ		50g12						
Fission	chem	50b2,50o1,50d1, 48SP	Fission	chem	42H6,48SP	Fission	chem	42H6,48SP
	d short Cs	50b2,50o1,50d1		d $1\text{-}2^m$Cs	42H6		d short Cs	50b2,50o1,50d1
	p 3.7^hLa	42H6		p 74^mLa	42H6		p 19^mLa	42H6

144 56 88			145 56 89		
τ	short	50d2	τ	short	50d1
Fission	chem	50d2	Fission	chem	50d1
	d short Xe	50d2		d 0.8^sXe	50d1
	p 275^dCe	50d2		p 1.8^hCe	50d1

Neutron Cross Sections for Natural Element			133 57 76			134 57 77
	E_n = 0.025ev		τ	4.0^h	49N8	
σ_a	8.8	49P3				
σ_t	26	42R2				
	10	42B4	K		49N8	
			β^+ few %	1.2	49N8	
			e^-	0.26 s	49N8	
			γ	0.8 a	49N8	
			K X-ray		49N8	
	Graphs Available					
σ_t	0.01-1000ev	50Ad,47GIF	Cs-α-4n	ms,chem	49N8	

135 57 78			136 57 79			137 57 80		
τ	19.5^h	48C3	τ	9.5^m	49N8	τ	$>400^y$	48C3
				9.0	49R7		>30	48I5
				10	47M2			
K		48C3	K ~67%		49N8			
γ	0.76 a	48C3	β^+ ~33%	2.1 s	49N8			
				2.1 a	47M2			
X-ray		48C3		1.8 a	49R7			
X/γ = 50		48C3						
			γ		49R7			
			No γ		47M2			
			X-ray		49N8,49R7			
Cs-α-2n	ms	49N8	Ba^{135}-d-n		49R7			
	chem,σ	48C3	Ba^{136}-d-2n		49R7			
			Ba-d-n	chem	47M2			
			Cs-α-n	chem	49N8			
				chem,σ	48C3		d 36^hCe ms	48I5

138
57 81

τ	17.5^h	43W2,49B3
K		43W2
γ	0.88 a	43W2
Ba K X-ray		43W2
La-γ-n	threshold = 12.9	49B3
Ba-d-n	chem	43W2
Ba-p-n	chem	43W2

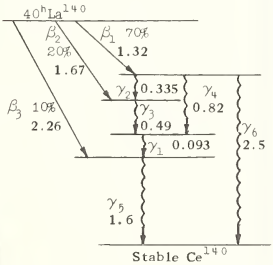
	0.089%	47I9
No observable activity		47I9

139
57 82

	99.911%		47I9
I	7/2	S	34A2
μ	2.760		49Po
		I	49C2,49D13
		S	40W8
Levels	0.163		Ba^{139}
	1.05		
	0.184		Ce^{139}
	0.8 } ?		
	1.8 } ?		
	σ's		
(th n,γ)40^hLa	8.4		47S33
	>7		46B25
(th n,γ)	8.8		49P3
(1Mev n,γ)40^hLa	5mb		49H28
(20Mev d,4n)36^hCe	0.002		48C3
(40Mev d,4n)36^hCe	0.06		48C3
(60Mev d,4n)36^hCe	0.04		48C3
(20Mev d,2n)140^dCe	0.09		48C3

140
57 83

τ	40.0^h	50b7,43W2
	39.5	46B25
Proposed decay scheme		49B36
Fission	ms	48H25
	chem	50b7,48SP
La-d-p	chem	43W2
La-n-γ	chem	42G1,43W2
Ce-n-p	chem	43W2
	d 12.8^{d}Ba	42H6,50f4



β_1^-	70%	1.32	s	49B36
	20%	0.90	s	4601
β_2^-	20%	1.67	s	49B36
	70%	1.40	s	4601
		1.45	s	47R1
β_3^-	10%	2.26	s	49B36
	10%	2.12	s	4601
γ_1		0.093?	sc	49B36
γ_2		0.335	sc	49B36
		0.333	s	4601
	2%*	0.335	s	47R1
	1%*	0.335	s	46M6
γ_3		0.490	sc	49B36
		0.505	s	4601
	5%*	0.49	s	47R1
	7%*	0.49	s	46M6
γ_4		0.820	s	49B36
		0.832	s	4601
	10%*	0.87	s	47R1
	15%*	0.83	s	46M6

γ_5		1.6	s	49B36
		1.61	s	4601
	77%*	1.65	s	47R1
	74%*	1.63	s	46M6
γ_6		~2.5	s	49B36
		2.52	s	4601
	6%*	2.3	s	47R1
	4%*	2.3	s	46M6
	3%**	2.49	γn	47W1,47W9
γ's from conversion lines				49C22
0.068, 0.109, 0.131, 0.155, 0.173, 0.242, 0.266, 0.323, 0.328, 0.434, 0.487, 0.524				
$\beta\gamma$ and $\gamma\gamma$ coincidences				48M14,4601, 47M3
Levels in La^{140}		0.54 others ?		Ba^{140}
		σ's		
(th n,$\gamma\beta$)28^dCe		~3		49K4

* % of γ's
** % of disintegrations

141 57 84			142 57 85			143 57 86		
τ	3.7^{h}	50k7	τ	74^{m}	42H6	τ	19^{m}	50g10
	3.5	42H6		77	50k7		15	43H8
β^-	2.8 a	50k7	β^-		50k7			
No γ ?		50k7	γ		50k7			
Fission	chem	50k7,42H6,48SP	Fission	chem	50k7,42H6,48SP	Fission	chem	39H4,39H5
	d 3^{s}Xe	50b2					d 1^{s}Xe	50b2
	d 18^{m}Ba	42H6		d 6^{m}Ba	42H6		d $<0.5^{m}$Ba	39H4,39H5
Probably	p 28^{d}Ce	42H6,50b8,50k7					p 33^{h}Ce	50g10

144 57 87			145 57 88		
τ	short	50d2	τ	short	50d1
Fission		50d2	Fission		50d1
	d $\sim 1^{s}$Xe	50d2		d 0.8^{s}Xe	50d1
	p 275^{d}Ce	50d2		p 1.8^{h}Ce	50d1

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Neutron Cross Sections for Natural Element			135 58 77			136 58 78		
	$E_n = 0.025$ev		τ	$\sim 16^h$	48C3		0.193%	47I9
σ_a	0.65	49P3					0.195	49H3
	0.64	49H2						
σ_t	~ 3	42R2	β^+	~ 0.4	48C3			
	~ 15	42B4						
	Other energies							
σ_t		49H16						
			La-d-6n		48C3			
			p	19.5^hLa	48C3			

137 58 79			138 58 80			139 58 81		
τ	36^h	48C3		0.250%	47I9	τ	140^d	48C3, 48P1
				0.265	49H3			
K		48C3				K		48P1, 47M12
No β^+		48C3				γ	0.18 sc, ac	48C3
γ	0.28 ac	48C3					0.184 sc	48P1
	0.75 a	48C3					0.8 a	48P1
							1.8 a	48C3
La K X-ray		48C3				La K X-ray		47M12, 48P1
La-d-4n	σ	48C3				La-d-2n	chem, σ	48P1, 48C3
						Ba-α-2n	chem	48P1
p	$> 400^y$La	48I5						

140
58 82

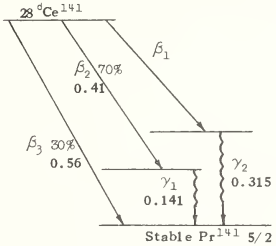
	88.48%	47I9
	88.45	49H3
Levels	1.6	La^{140}
	2.5	
	others ?	La^{140}, Pr^{140}

σ's

(th n,γ) $_{28}{}^{d}Ce$	0.31	49K4
	<0.4	46B25
(1Mev n,γ) $_{28}{}^{d}Ce$	4.8mb	49H28

141
58 83

τ	28^{d}	50b8
	30	46B25
	30.6	48P1
	32.2	48S28



β_1^-	Not observed		
β_2^- 70%	0.41	s	48S28
	0.4	a	46B25
	0.44	a	49M15
β_3^- 30%	0.56	s	48S28
	0.55	a	50b8
	0.66	a	48P1
γ_1	0.141	sc	48S28
	α=0.2		48S28
	0.13	a	49M15
	0.21	a	50b8
γ_2	0.315	s	49T12
	0.4	a	49M15
	impurity ?		49M15
$\beta\gamma$ coincidences only for			
E_β <0.25. No $\gamma\gamma$			49T12
$3\times10^{-7\,s}$>$\beta\gamma$ delay >$10^{-3\,s}$			49B9
$\beta\gamma$ delay of $70^{\mu s}$			47H24
βe^- coincidences			49M15, 48S28

Fission	ms	46H5
Ce-n-γ	ms	48I5
	chem	50b9, 46B25
Fission	chem	50b9, 48SP
Ba-α-n	chem	48P1
Ce-d-p	chem	50b8, 50b9, 48P1
Ce-n-2n	chem	50b9, 48P1
Pr-n-p	chem	43P3
	d 3.7^{h}La	50k7, 50b8

142
58 84

	11.07%	47I9
	11.10	49H3

σ's

(th n,γ) $_{33}{}^{h}Ce$	0.95	49K4
	1.1	46B25
(~1Mev n,γ) $_{33}{}^{h}Ce$	3.6mb	49H28

143
58 85

τ	33^{h}		42E3, 50b9,
			46B25
	34		48P1
β^-	1.36	a	50b9
	1.3	a	48P1, 46B25
γ	0.5	a	50b9
	0.6	a	48P1

Ce-n-γ	ms	48I5
	chem, σ	46B25
Ce-d-p	chem	48P1, 50b9
Fission	chem	50b9
	Not produced by	
Ce-n-2n		50b9
Ba-α		48P1
	d 19^{m}La	50g10
	p 13.8^{d}Pr	50b9

144
58 86

τ	27.5^{d}		50b10
	290		44J4
	310		43B2, 43H8
β^-	0.348	s	50n8
	0.30	s	47P10
	0.3	a	50b10
No γ			43B2, 50s23

Fission	ms	48H25
	chem	50b10, 48SP
	d ~1^{s}Xe	50d2
	p 17.5^{m}Pr	43H8, 50n8

145 58 87	146 58 88	
τ 1.8^{h} 50b11	τ 14.6^{m} 46PP 11 46G7 15 43H8	
Fission chem 46PP	Fission chem 46PP,46G7	
d 0.8^{s}Xe 50d1 p 4.5^{h}Pr 50b11,50k10	p 25^{m}Pr 46PP,46G7	

Neutron Cross Sections for Natural Element				140 59 81				141 59 82			
	E_n = 0.025ev			τ	3.6^m		45H2		100%		42H2,48I2
σ_a	11.2		49P3		3.4		42D7				
					~1.5		49W2				
				β^+	2.5	a	45H2	I	5/2	S	29W1
					~2.4	a	49W2				
					2.4	cc	42D7				
				K ~66%			49W2				
				γ ~2%	1.2	a	49W2				
				X-ray	0.038	a	49W2	Levels	0.141		Ce^{141}
									0.315	?	
									1.05		Nd^{141}
									σ's		
								(th n,γ)19^{h}Pr	13		46B25
									8.5		48W16
								(th n,γ)	11.2		49P3
								(~1Mev n,γ)19^{h}Pr	11mb		49H28
				Pr-γ-n	relσ		49P5,48W13	(9Mev d,2n)2.4^{h}Nd	0.9		
				threshold = 9.4			49H17	(19Mev d,2n)2.4^{h}Nd	0.3		
					9.8		49B3	(19Mev d,3n)3.3^{d}Nd	0.08		49W2
				Pr-n-2n			42D7	(10Mev p,n)2.4^{h}Nd	0.03		
								(9Mev d,p)19.3^{h}Pr	0.1		
				d 3.3^{d}Nd			49W2	(19Mev d,p)19.3^{h}Pr	0.06		

142 59 83								143 59 84			
τ			18.9^h				48K21	τ	13.8^d		50b13
			19.2				46B25		13.7		49B56
			19.3				42D7		13.5		48P1
β^-	0.215	a$\beta\gamma$	49M12	γ	~0.17	a	49M12	β^-	0.932		49F18
	0.35	a$\beta\gamma$	49J3						0.922		49B56
	2.23	s	47P10		0.134	sc			0.920	s	49T12
	3 groups present		47P10		0.329	sc	48C23		0.93	s	48S28
	2.14	s	42D7		0.490	sc		Absorption values in agreement:			
					0.624	sc			49M15,48P1,46B25,44J4		
β/γ ~5			47P10		~1.3	s	47P10				
β/γ ~25			42D7					No γ			50s20,50b12,48P1
					~1.65	s	47P10				
$\gamma\gamma$ coincidences			49J3,49M12		1.53	a coin	49J3	No delayed coincidences			49B9
No $\beta\beta$ coincidences			49M12		1.74	a coin	49M12				
No γ in coincidence with 2.2β			49M12								
				γ's do not produce Be-γ-n			47W1	Level	0.5		Ce^{143}
Pr-n-γ	chem		48K21	La-α-n				Fission	ms		46H5
	σ		48W16,46B25	Ce-p-n			42D7		chem		43H8,50b12
Ce-d-2n			48P1	Pr-d-p				Ce-d-n			48P1
									d 33^{h}Ce		50b9,50b12,50s21, 46PP,46B25

144 59 85				145 59 86				146 59 87			
τ	17.5^{m}		50n10,50s23	τ	4.5^{h}		50k10	τ	24.6^{m}		46PP
	17		46G6,43H8		4.7		50b11		25		46G7
	18		43G14								
β^-	3.07	s	50n8	β^-	3.2	a	50k10	β^-	~3	a	46PP
	2.99	s	47P10								
	3.1	a	43B2,43H8, 46G6	No γ			50k10	γ	1.4	a	46PP
									hard		46G7
γ	0.135	sc	50n8								
weak	0.22	a	50s23								
weak	1.25	a	50s23								
Fission	ms		48H25	Fission	chem		50b11,50k10	Fission	chem		46G7,46PP
	chem		50n10,48SP								
d 275^{d}Ce			43H8,50n10	d 1.8^{h}Ce			50b11,50k10	d 15^{m}Ce			46G7

Neutron Cross Sections for Natural Element			139 60 79			140 60 80		
	E_n = 0.025ev							
σ_a	45	49P3				τ	3.3^d	49W2
	54	49H2						
σ_t	65	42R2				K		49W2
	72	42B4				γ weak	1.2	49W2
						Probably belongs to Pr^{140}		49W2
						K X-ray		49W2
	Graphs Available							
σ_t	0.04-10ev	47S30,47GIF				Pr-d-3n	chem,σ	49W2
						p 3.6^mPr		49W2

141 60 81			142 60 82			143 60 83		
τ	2.42^h	49W2		27.13%	48I2		12.20%	48I2
	2.5	42K3		26.80	48M27		12.12	48M27
K ~98%		49W2						
β^+ ~2%	0.7 a	49W2						
	0.78	42K3						
γ ~2%	1.05 a	49W2						
Pr K X-ray		49W2						
			Levels	~1.3	Pr^{142}			
				~1.65				
				others ?				
				σ's			σ's	
			(pile n,γ)	<12	49H12	(pile n,γ)	240	49H12
Pr-p-n	σ	49W2,42K3						
Nd-n-2n		42K3						
Nd-γ-n		42K3						
Pr-d-2n	chem,σ	49W2						

144
60 84

	23.87%		48I2
	23.91		48M27
Levels	0.135		Pr^{144}
	1.25		
	others ?		
	σ's		
(p1le n,γ)	<15		49H12

145
60 85

	8.30%		48I2
	8.35		48M27
	σ's		
(p1le n,γ)	<30		49H12

146
60 86

	17.18%		48I2
	17.35		48M27
Level	1.4		Pr^{146}
	σ's		
(th n,γ)11^{d}Nd	1.4		46B25
(p1le n,γ)	<20		49H12

147
60 87

τ		11.0^{d}		47M28,50m1
		11.1		46B25
		12.1		47M22
β⁻	40%	~0.4	a	47M28,50m1
	60%	0.90	a	47M28,50m1
		0.76		47M22
		0.8		46B25
γ	40%	~0.58	a	47M28,50m1
		0.45	a	47M22
e^{-}		0.03	a	47M28,50m1
X-ray		~0.040	a	47M28,50m1
Nd-n-γ		chem		50m1,48K21, 47M28
		σ		46B25
Fission		chem		47M28,50m1
	p	4^{y}Pm		50m3

148
60 88

	5.72%		48I2
	5.78		48M27
	σ's		
(th n,γ)2^{h}Nd	2.8		46B25
(p1le n,γ)	<45		49H12
Nd-n-γ	chem		50m1,48K21, 47M28
	σ		46B25
Fission	chem		47M28,50m1
	p	4^{y}Pm	50m3

149
60 89

τ		1.7^{h}		47M28,50m5
		2.00		46B25
β⁻		1.5	a	47M28,50m5
		1.6	a	46B25
γ or X-ray				47M28,50m5
Nd-n-γ		chem		47M28,50m5
		σ		46B25,49H12
Nd-γ-n,threshold = 7.4				49H17
	p	47^{h}Pm		47M28,50m5

150 60 90					151 60 91		
5.60%		48I2	τ	$<8\times10^{10}$ y	34L3	τ short	50m5
5.69		48M27					
			β^-	~0.011 a	34L3		
σ's (pile n,γ)	<45	49H12					
			Natural source		34L1	Nd-n-γ	50m5
			Mass assignment		48K22		
						p 12^mPm	50m5

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143 61 82			
τ	$\sim 200^{d}$		42W2
	$\sim 1^{y}$		48W14
K			48W14
γ	0.67	a	42W2
Pr-α-2n			48W14
Nd-d-n			43K1
Pr-α			42W2

144 61 83			

145 61 84			
Levels	0.242		Sm^{145}
	0.95		

146 61 85			
τ	2.7^{h}		43K1
β^-	2		43K1
γ			43K1
Nd-d-n			43K1
Nd-p-n			43K1
Nd-α-p			41L2

147 61 86			
τ	4^{y}		50m3, 50b15
	3.7		50S26
β^-	0.223	s	49P20, 46L8
	0.227	s	49L23
No γ			50S26, 50m3, 47M28
Level	~ 0.5		Nd^{147}
(th n,γ)5.3^{d}Pm	σ's 60		47P4
Fission	ms		48H25
	chem		50m3
Nd-n-$\gamma\beta$	chem		47M28, 50m3
d 11^{d}Nd			50m3, 48H25

148 61 87			
τ	5.3^{d}		43K1, 47P4
β^-	~ 2.5	a	47P4
	2		43K1
γ	~ 0.8	a	47P4
Pm^{147} (from fission)-n-γ	ms, σ		47P4
Nd-p-n			43K1
Nd-d-2n			43K1

149 61 88	150 61 89	151 61 90
τ 47^h 47M28, 50m4 47.5 46B25 49 48K21 β^- 1.1 a 50m4, 46B25, 47M28 0.98 a 49M19 γ weak 0.25 a 47M28, 50m4 ~0.2 a 49M19 X-ray ? 50m4 Coincidences between 0.98β and 0.2γ 49M19 $\beta\beta$ coincidences 49M19 Fission ms 47I6 chem 47M28, 50m4 Nd-n-$\gamma\beta$ chem 50m5, 48K21, 47M28 d 1.7^{h}Nd 47M28, 50m4		τ 12^m 50m5 β^- 1.9 49K2 γ 49K2 Nd-n-$\gamma\beta$ 49K2, 50m5

152 61 91	153 61 92	154 61 93
	τ < 5^m 50W6 p 47^{h}Sm 50W6	

155 61 94	156 61 95	
	τ $<5^{m}$ 50W9 $p \sim 10^{h}$ Sm 50W9	

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	8100	49H2
	10,600	49P3
σ_t	8800	

Averaged over Maxwell distribution with kT = 0.025ev. From data of 47S31

Resonances

E_o	σ_o	Γ	
0.096ev	15,500	0.074	47S31
0.096	12,800	0.070	46B26
Assigned to Sm^{149}			47L19
10	2,800		47S31
10		0.1	49G9
Assigned to Sm^{152}			49G9
33			47S31

Graphs Available

σ_t	0.02-70ev	47S31,47GIF
	0.02-0.17ev	46B26,47GIF

α activity of Sm

Natural element α emitter		32H1, 36H4,33L1
τ (total Sm)	0.93×10^{12} y	48L9
	1.0×10^{12}	36H4
Radioactive isotope assigned to Sm^{152}		48D2
α	2.14 photographic plate	46C1
	2.2 cc	36H4
No α activity found from Sm-200Mev p		49T13

144
62 82

3.16%	48I1
2.95	48M27

145
62 83

τ	>150 d		48C9
	>72		47I7
	60		42K3
γ	0.242	sc	48C9
	0.95	a	48C9
Sm-n-γ	ms		47I7
Sm-d-p			42K3
Nd-α-n			42K3

146
62 84

147
62 85

15.07%	48I1
14.62	48M27

148
62 86

	11.27%	48I1
	10.97	48M27
Level	~0.8	Pm^{148}

149
62 87

	13.84%	48I1
	13.56	48M27
Levels	0.25	Pm^{149}
	~0.5 ?	Eu^{149}

σ's

(th n,γ) 65,000

Averaged over Maxwell distribution kT = 0.025ev. From data of 47S31. 47L19,48I1

150
62 88

	7.42%	48I1
	7.27	48M27
Sm-n-γ		49K15

E_γ (max) = 6.6

151
62 89

τ	$\sim 10^3$ y		49M5
	~20		47I7
β^-	0.074	s	49M5
	0.079	s	49K5
	0.06	a	48P7
No γ ?			48P7
No γ			49M5
γ	0.021	pc	49S35

β spectrum may have forbidden shape 49M5

L X-ray 49S35

Sm-n-γ	ms	47I7
Fission	chem	49M5

152
62 90

	26.63%	48I1
	27.34	48M27

α activity assigned to this isotope 48D2

See α activity box

Levels ? Eu^{152}, $Eu^{152,154}$

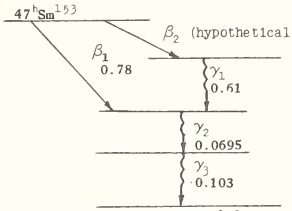
σ's

(th n,γ)47^hSm	135	47S33
	280	46B25

$^{153}_{62}$ 91

τ	47^h		46B25,42K3,50W6

Proposed decay scheme 49M2



β_1^-	0.78	a		48B5
	0.73	a		50W6
γ_1 weak	0.61	a coin		48B5
	~0.6	s		46M6
	0.57	a		50W6
γ_2	0.0695	sc		48H18
	$\alpha \sim \infty$	K/L ~0.5		49M2
γ_3	0.103	sc		48H18
	0.102	sc		48C9
	0.11	s		46M6
	0.11	a coin		48B5

Eu K,L X-rays 46B25,48B5
(K X-ray)/β ~0.7 46B25
No coincidences delayed > 1.5$^{\mu s}$ 48B5

βe^-, βX, 0.11$\gamma\beta$, 0.11γX, XX coincidences 48B5

Sm-n-γ ms 46H8
σ 46B25,47S33
Fission 50W6,48SP
Sm-γ-n 41L2

Sm-n-2n
Sm-d-p
Nd-α-n
} 42K3
d <5^{m}Pm 50W6

$^{154}_{62}$ 92

22.53%		48I1
23.29		48M27

Levels ? Eu^{154}
$Eu^{152,154}$

σ's
(th n,γ)25^{m}Sm 5.5 47S33

$^{155}_{62}$ 93

τ	25^m		50W7
	21		42K3,38P5
β^-	1.9	a	50W7
	1.8		42K3
γ	~0.3	a	50W7

Sm-n-γ 41L2,38P5,36H1
σ 47S33
Sm-d-p 42K3
Fission 50W7
Assignment on basis of fission yield and decay energy

$^{156}_{62}$ 94

τ	~10^h		50W9
β^-	~0.8	a	50W9

Fission chem 50W9

Neutron Cross Sections for Natural Element	146 63 83	147 63 84
$E_n = 0.025$ev σ_a 4200 49P3 σ_t 4800 47S31 4120 42R2 Resonances E_o σ_o Γ -0.011ev 5570 0.08 47S31 Assigned to Eu^{151} 46B26 0.465 5670 0.2 47S31 Assigned to Eu^{153} 46B26 3.3 47S31 Assigned to Eu^{151} Additional resonances at 9.2, 22ev 47S31 Graphs Available σ_t 0.007-70ev 47S31, 47GIK 50Ad		τ 53^d 50m9 40 43E6 γ 0.42 1.0 50m9 γ's ~ equal intensity Sm-d-2n 50m9, 43K1

148 63 85	149 63 86	150 63 87
	τ 14^d 50m9 γ or X-ray 50m9 e^- ~0.5 50m9 Sm-d-n 50m9	τ 27^h 38P5 β^+ 38P5 Eu-n-2n 38P5

151
63 88

	47.77%		48H31
I	5/2	S	35S1
μ	3.4	S	38S9
q	~+1.2	S	38S10
σ's			
(th n,γ)9^{h}Eu	1400		47S33
	1500		46B25
(pile n,γ)	5200		49H4
(th n,γ) long Eu	2500 per Eu atom		46B25
(th n,γ) long Eu	1500 per Eu atom		47S33

152
63 89

τ_1	9.2^h		38P5
	9.3		46B25
K			46B25, 47M23
β^-	0.36	a	47M23
	1.8	a	47M23
	1.88	s	39T1
γ	0.123	sc	39T1
	0.163	sc	
	0.725	sc	
	1.0	a	47M23
K/β = 0.6			46B25
	0.22		49H4
Eu-n-γ	ms,σ		49H4, 46H8
	chem,σ		48K21, 41F3
Eu-n-2n			38P5
Eu-d-p	chem		41F3

τ_2	5.3^y		49H4
K			49M5, 49H4
β^- 80%	0.9	a	49M5
20%	1.7	a	49M5
γ	~0.3	a	49M5
probably corresponds to soft γ's of Eu^{152,154}			49M5
	~1.2	a	49M5
probably associated with K capture			49M5
K/β = 5			49H4(49M5)
σ's			
(pile n,γ)	3200		49H4
Eu-n-γ	ms,σ		49H4

Radiation of Eu^{152} produced by Eu-n-γ not distinguishable from that of Eu^{154}. Above radiation assigned by comparison of radiation of mixture with that of fission product Eu^{154}. See also Eu^{152,154}.

152,154
63 89,91

K					47M23, 46B25
β^-	0.75	s			48S24
	0.751	s			48C9
	1.575	s			48S24
	1.57	s			48C9
	1.4	a			48K7
	48C9		48S24		
γ	0.040	sc			
	0.122	sc	0.123	sc	
	0.247	sc	0.247	sc	
	0.286	sc	0.286	sc	
	0.342	sc	0.344	sc	
	0.408	sc	0.412	sc	
			0.442	s	
			0.772	s	
			0.959	s	
			1.082	s	
			1.402	s	
γ	1.23	a			48C9
	0.9	a			48K7
See also					48C26
Eu-n-γ					48S24
Eu-d-p	chem				41F3, 48K7

153
63 90

	52.23%		48H31
I	5/2	S	35S1
μ	1.5	S	38S9
q	~+2.5	S	38S10
Levels	0.102		Gd^{153}, Sm^{153}
	0.172		Sm^{153}
	0.78		Sm^{153}
σ's			
(pile n,γ)5.4^{y}Eu	240		49H4

154
63 91

τ	5.4^y		49H4
β^- 50%	0.3	a	49H4(49M5)
40%	0.7	a	
10%	1.9	a	
γ	~1.2	a	49H4, 49M5
0.3 and 0.7 β's probably in coincidence with ~1.2γ			49M5
K/β < 0.05			49H4

Radiation of Eu^{154} produced by natural Eu-n-γ not distinguishable from that of Eu^{152}. See also Eu^{152,154}.

σ's			
(pile n,γ)	880		49H4
Eu-n-γ	ms,σ		49H4
Eu^{153} (fission)-n-γ			49M5

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155
63 92

τ		1.7^{y}		49H4
		2		50W10
β^-	80%	0.154	s	49M5
	20%	0.243	s	49M5
		2.23	a	50W10
γ	60%*	0.085	sc	49M5
	40%*	0.099	sc	49M5
		0.0844	critical a	50W10

*% of γ's

0.154 β in coincidence with γ 49M5
No $\gamma\gamma$ coincidences 49M5
No delayed $\beta\gamma$ coincidences 49M5

σ's

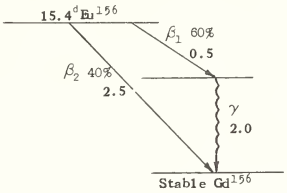
(pile n,γ)	7,900	49H4
	14,000	47I7
	~30,000	49M5

From expected and observed fission yields.

Sm-n-$\gamma\beta$	ms	47I7
Fission	chem	48SP, 50W10
Eu-n-γ, n-γ		49H4

156
63 93

τ	15.4^{d}		50W9, 49H4



β_1	~0.5	a	50W9
β_2	2.5	a	50W9
γ	2.0	a	50W9

Eu^{155}-n-γ	ms	47I7
Eu-n-γ	ms	49H4
Fission	chem	50W9, 48SP

d 10^{h}Sm 50W9

157
63 94

τ	15.4^{h}		50W8
β^- 75%	~1.0	a	50W8
25%	~1.7	a	50W8
γ	0.2	a	50W8
	0.6	a	50W8

Fission chem 50W8, 48SP
Mass assignment from fission yield and decay energy.

158
63 95

τ	60^{m}	50W8
β^-	~2.6	50W8

Fission chem 50W8
Mass assignment from fission yield.

Neutron Cross Sections for Natural Element	α activity of Gd or Tb	151 64 87
E_n = 0.025ev σ_a 36,700 49H2 σ_t 48,000 47B15 42,000 47S31 See also 48WH Resonance E_o σ_o Γ 0.028ev 45,000 0.24 47B15 0.044 32,000 0.10 47S31 Graphs Available σ_t 0.002-0.2ev 47B15,47GIF 0.005-0.2ev 47S31,47GIF	τ ~7^m 49T13 α 4.2 49T13 τ ~4^h 49T13 α ~4 49T13 α/K capture~1% 49T13 Both activities produced by Gd-200Mev p 49T13 Dy-200Mev p 49T13 Not produced by Sm-200Mev p 49T13 No α activity with τ <10^{12}y found in natural Gd 48K27	

152 64 88	153 64 89	154 64 90
0.20% 48H31 0.2 41W13 σ's (th n,γ)225^{d}Gd <125 47S33 No activity found	τ 225^d 49K1 154 49H11 155 48H28 K 49K1,48H28 γ 0.026* pc 49S35 0.100 sc 49K1 0.102 sc 48C9 others? 48H28,48C9, 49H11 0.260 a 49H11 Eu K X-ray 49K1,49H11 Levels ~0.2 ? Tb^{153} ~0.45 ? Gd-n-γ ms,σ 47I7 chem 49K1 Eu-d-2n chem 41F3,48K7 * Probably in Tb^{161} 50S7	2.15% 48H31 2.86 41W13 Levels ~0.3 ? Tb^{154} ~1.2 Tb^{154},Eu^{154} See also Eu^{152,154}

155
64 91

	14.78%	48H31
	15.61	41W13
Levels	0.085	Eu^{155}
	0.099	
	σ's	
(pile n,γ)	69,000	47L19

156
64 92

	20.59%	41W13,48H31
Level	2.0	Eu^{156}

157
64 93

	15.71%	48H31
	16.42	41W13
Levels	0.2	Eu^{157}
	0.6	
	σ's	
(pile n,γ)	240,000	47L19

158
64 94

	24.78%	48H31
	23.45	41W13
	σ's	
(pile n,γ)18^hGd	4.5	49B1
	4	47S33
Gd-n-γ		49K15
E_γ(max) = 6.3		

159
64 95

τ	18.0^h		48K3,49B1
	17.9		48K21
	20.0		47S33
β^-	0.85	a	48K3
	0.95	a	49B1
	0.9	a	48K21
γ	0.055	a	49B1
	0.38	a	49B1
	~0.3	a	48K3
	0.35	a	48K21
No delayed coincidences			49M26
Gd-n-γ	chem,σ		49K1,49B1
Gd-d-p			48K3
Not produced by Tb-n-p			48K3
Not p 6.7^d Tb chem			48K21

160
64 96

	21.79%	48H31
	20.87	41W13
	σ's	
(pile n,γ)3.6^mGd	0.18	49B1
	0.1	49D17
(pile n,$\gamma\beta$)6.7^dTb	0.16	49B1

$^{161}_{64}$ $_{97}$					
τ	3.6^{m}		49B1	No long lived Gd with half life between 0.3^{y} and 30^{y} found in fission 49M5	
	3.3		49D17		
	4.5		46I3		
β^{-}	1.5	a	48K21		
	~2		49D17	Gd-n-γ emits conversion e^{-} with mean half life $<10^{-7}$ sec relative to the capture γ's 48S32	
γ	0.37	a	48K21		
e^{-}	~0.066		49D17		
Gd-n-γ	σ		49D17,49B1		
	p 6.75^{d} Tb		49K23		

Neutron Cross Sections for Natural Element			α activity of Tb or Gd			151 65 86
	$E_n = 0.025$ev		τ	$\sim 7^m$	49T13	
σ_a	55	49P3	α	4.2	49T13	
			τ	$\sim 4^h$	49T13	
			α	~4	49T13	
			α/K capture	~1%	49T13	
			Both activities produced by			
			Gd-200Mev p		49T13	
			Dy-200Mev p		49T13	
			Not produced by			
			Sm-200Mev p		49T13	

152 65 87			153 65 88				154 65 89			
τ	4.5^h	48W12	τ	5.1^d		48W12	τ	17.2^h		48W12
K		48W12	K			48W12	K			48W12
K X-ray		48W12	e^-	0.15	a	48W12	β^+	2.6	a	48W12
				0.4	a	48W12	γ	1.4	a	48W12
			K,L X-rays			48W12	e^-	~0.22	a	48W12
								~1.0	a	48W12
							K,L X-rays			48W12
Eu-α-3n	chem	48W12	Eu-α-2n	chem		48W12	Eu-α-n	chem		48W12
							Eu-α-3n	chem		
							Gd-p-n	chem		

155
65 90

τ	$\sim 1^{y}$		48W12
K			48W12
e^-	0.1	a	48W12
K,L X-rays			48W12
Eu-α-2n	chem		48W12

156
65 91

τ	5.9^{d}		49B1
γ	~ 0.3	a	49B1
	1.1	a	49B1
e^-	soft		49B1
Gd-d ?			49B1
Gd-p			49B1

157
65 92

158
65 93

τ	3.6^{m}		38P5
β^+			38P5
Tb-n-2n			38P5

159
65 94

	100%		48H31
I	3/2	S	34S2
Levels	0.055	?	Gd^{159}
	0.35	?	
	σ's		
(th n,γ)73^{d}Tb	>22		46B25
(th n,γ)	55		49P3

160
65 95

τ	72.5^{d}		48K21
	73.5		46B25
	77.3		48C9
β^-	0.546	s	48C9
	0.882	s	48C9
	0.71	a	48K3
	0.75	a	46B9
γ	0.086	s	48C9
	0.195	s	
	0.212	s	
	0.297	s	
	1.15	a	
3.3^{h} activity formerly assigned here shown to be Dy^{165}			49F7
Tb-n-γ	ms		47I7
	σ		46B25
Gd-d-2n			48K3

$^{161}_{65}$ $_{96}$		
τ 6.75^{d} 49B1 7.0 49K1 β^{-} 0.52 a 49B1 0.5 a 49K1 γ 0.026? pc 50S7 0.05 a 49B1 no harder γ 49B1 ~0.045 a 49K1 5.5^{d} activity formerly assigned here probably mixture of 6.75^{d}Tb and 5.9^{d}Tb 49B1 Level 0.37 Gd^{161} Gd-p 49B1 Gd-d-n 49B1, 48K3 Gd-n-$\gamma\beta$ chem, σ 49B1 d 3.6^{m}Gd 49K23	No long lived Tb with half life between 0.3^{y} and 30^{y} formed in fission. 49M5	

Neutron Cross Sections for Natural Element	α activity of Dy or Ho	155 66 89
$E_n = 0.025$ev σ_t 1150 47B15 Resonances E_o σ_o Γ -1.01ev 79,000 0.20 47S31 1.74 5.5 } 47S30 ~20 ? } Graphs Available σ_t 0.007-0.2ev 47GIF, 47B15 0.07-20ev 47GIF, 47S30 0.02-0.4ev 47GIF, 47S31	τ 20^m 49T13 α 4.1 49T13 Produced by Dy-200Mev p 49T13 Not produced by Sm or Gd-200Mev p 49T13	

156 66 90	157 66 91	158 66 92
0.052% 49I2		0.0902% 49I2

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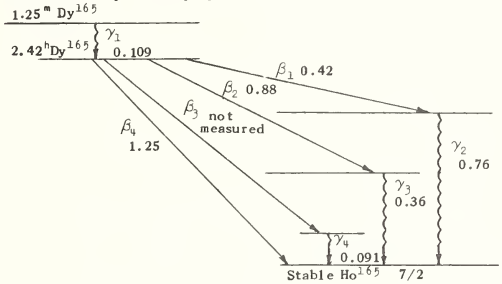
159			160			161		
66	93		66	94		66	95	
τ	146^{d}	49K2		2.29%	49I2		18.88%	49I2
K		49K2						
Tb K,L X-rays		49K2						
e^{-}	soft	49K2						
			Levels	0.086 0.195 0.212 0.297 1.15 } ?	Tb^{160}	Levels	~0.05 ~0.2 ~0.65	Tb^{161} Ho^{161} Ho^{161}
Dy-n-γ		49K2						

162			163			164		
66	96		66	97		66	98	
	25.52%	49I2		24.97%	49I2		28.18%	49I2
Level	1.1	Ho^{162}	Level	~0.45	Ho^{163}			
						σ's		
						(th n,γ) 1.3^{m}Dy	2860	47G14
						(th n,γ) 2.4^{h}Dy	2200	46B25
							2620	47S33

165
66 99

τ_1	1.25^m	46F1	τ_2	2.42^h	47S14
	1.2	48H36		2.33	47S33, 46B25

Tentative decay scheme proposed by 47S14



$Dy^{164}(n,\gamma)$ cross sections ~equal for both activities, indicating that only 1.25^mDy is formed directly. But growth of 2.42^hDy has not been observed. Part of 1.25^mDy may decay by β^- directly to Ho^{165}. 47I3

β_1^-	0.42	s	47S14		
β_2^-	0.88	s	47S14		
β_3^-	not measured				
β_4^-	1.25	s	47S14		
γ_1	0.109	sc	49C1		
	0.102	sc	48H36		
	0.18	ac	44F2		
γ_2	0.76	s	47S14		
	~1.0	s	46M6		
γ_3	0.36	s	47S14		
	0.37	s	46M6		
γ_4	0.091	sc	47S14		
~0.25 γ's per disintegration			47S14		
No delayed coincidences			49M26		

1.25^mDy produced by			2.42^hDy produced by		
Dy^{164}-n-γ		47I3	Dy-n-γ	ms	47I8
Dy-n-γ	σ	47G14, 46B25, 47S33	Dy^{164}-n-γ		47I3

σ's

(th n, γ) 81^hDy	5000	49K22

166
66 100

τ	81^h		49K22
β^-	0.4	a	49K22
Dy-n-γ, n-γ	chem, σ		49K22
	p 27.3^hHo		49K22

Neutron Cross Sections for Natural Element			α activity of Ho or Dy			159 67 92
	$E_n = 0.025$ev		τ	20^m	49T13	
σ_a	67	49P3	α	4.1	49T13	
σ_t	52	42B4				
	47	42R2				
			Produced by			
			Dy-200Mev p		49T13	
			Not produced by			
			Sm or Gd-200Mev p		49T13	

160 67 93			161 67 94			162 67 95		
τ	$\sim 20^m$	48W12	τ	60^d	48W12	τ	4.5^h	48W12
K ?		48W12	K ?		48W12	K, β^+		48W12
X-ray		48W12	e^-	0.16 a	48W12	e^-	0.3 a	48W12
				0.6 a	48W12	γ	1.1 a	48W12
			γ		48W12	K,L X-rays		48W12
			K,L X-rays		48W12			
Tb-α-3n		48W12	Tb-α-2n	chem	48W12	Tb-α-n	chem	48W12
			Dy-d-n, 2n, 3n	chem		Dy-p-n	chem	48W12
			Dy-p-n	chem				

163 67 96				164 67 97				165 67 98			
τ	7^d		48W12	τ	38.6^m		48W13		100%		34A1
					35		48W12				
					47		38P5				
K			48W12	β^-	0.7	a	48W12	I	7/2	S	35S2
e^-	0.4	a	48W12								
K,L X-rays			48W12								
								Levels	0.091		Dy^{165}
									0.36		
									0.76		
									σ's		
								(th n,γ) 27^hHo	60		47S33
									49		46B25
								(th n,γ)	67		49P3
								(38Mevα,3n)7.7^hTm	1.1		49W3
								(30Mevα,3n)7.7^hTm	5×10^{-4}		
								(38Mevα,2n)9.6^dTm	7×10^{-3}		
								(30Mevα,2n)9.6^dTm	0.1		
Dy-p-n	chem		48W12	Dy-p-n	chem		48W12	(19Mevα,2n)9.6^dTm	10^{-3}		
				Ho-n-2n			38P5	(38Mevα,n)85^dTm	10^{-4}		
				Ho-γ-n	rel σ		48W13	(30Mevα,n)85^dTm	3×10^{-3}		
								(19Mevα,n)85^dTm	0.2		

166 67 99			
τ	27.3^h		46B25, 48K21
	27.7		49C15
	26.8		49G1
β^-	1.8	a	49K22, 46B25
	1.88	s	49G1
	1.64	a	49C15
γ	0.073	s	49K2
	0.080	sc	49G1
	0.081	sc	49C15
1.5%	1.2	a	49G1
	0.92	a	49C15
No delayed coincidences			49M26
Ho-n-γ	ms		47I2
	σ		46B25, 47S33
	chem		49C15, 48K21
Dy-n-γ, n-$\gamma\beta$	chem		49K22
d	81^hDy		49K22

Neutron Cross Sections for Natural Element		161 68 93
$E_n = 0.025$ev σ_a 166 49P3 σ_t ~165 (extrapolation) 49B2 185 42B4 233 42R2 Resonance E_o σ_o ~0.5ev ⩾1700 49B2 Graph Available σ_t 0.03-0.7ev 49B2		

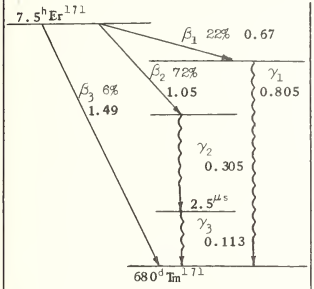
162 68 94	163 68 95	164 68 96
0.1% 41W8		1.5% 41W8

165 68 97	166 68 98	167 68 99
	32.9% 41W8	24.4% 41W8
	Levels 0.073 Ho^{166} ~1.0 Ho^{166} 1.7 Tm^{166} others ?	Levels 0.22 ? Tm^{167} 0.95 ?

168 68 100	169 68 101	170 68 102
26.9% 41W8	τ 9.4^d 48K11	14.2% 41W8
	β^- 0.33 s 48K11	
	No γ 48K11	
Levels 0.21 ? Tm^{168} 0.85 ?		
		σ's (th n,γ)7^h Er >7 46B25
	Er-n-γ chem 48K11	

171
68 103

τ	7.5^h	48K11
	5.7-7.1	46B25
	5.1	38P5



β_1^-	22%	0.67	s	48K11
β_2^-	72%	1.05	s	48K11
β_3^-	6%	1.49	s	48K11
γ_1		0.805	s	48K11
γ_2		0.305	s	48K11
γ_3		0.113	sc	48K11
		$\alpha = 1.3$		48D5
		$2.5^{\mu s}$ delay		48D5
other γ's ?				49C5

Er-n-γ		38P5
chem		48K11
σ		46B25

172
68 104

?
68

τ	2.5^s	49D16
IT		49D16
e^-	$\simeq 0.180$	49D16
Er-n-γ		49D16
σ(atomic) = 3		49D16

Long and short lived conversion electrons assigned to Er from K, L, M differences 49C5

Neutron Cross Sections for Natural Element			
	$E_n = 0.025$ev		
σ_a	118		49P3
σ_t	114		42B4
	69		42R2

165 69 96			

166 69 97			
τ	7.7^h		49W3
β^+	2.1	a	49W3
K			49W3
e^-	0.24	a	49W3
β^-?	~1	a**	49W3
γ	1.7	a	49W3
Er K X-ray			49W3
** Magnetic counter used			
Ho-α-3n	chem, σ		49W1
Er-p-n	chem		49W1

167 69 98			
τ	9.6^d		49W3
K			49W3
e^-	0.21	a	49W3
γ	0.22	a	49W3
	0.95	a	49W3
Er K X-ray			49W3
Er L X-ray (20% of K)			49W3
Ho-α-2n	chem, σ		49W1
Er-p-n	chem		49W1

168 69 99			
τ	85^d		49W3
K			49W3
e^-	0.16	a	49W3
β^-?	0.5	a	49W3
γ	0.21	a	49W3
	0.85	a	49W3
Er K X-ray			49W3
Er L X-ray (20% of K)			49W3
Ho-α-n, Er-p-n, Tm-n-2n	chem, σ		49W1

169 69 100			
	100%		34A1
I	1/2	S	34S3
Levels	?		Yb^{169}
	σ's		
(th n, γ) ^{129d}Tm	126		47S33
	95		46B25
(th n, γ) -	118		49P3
(36Mev α, 3n) $^{2.1d}$Lu	0.01		49W12

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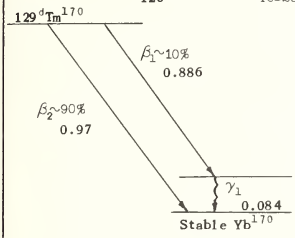
170
69 101

τ 129^{d} 48K21
127 46B9
125 46B23



$\beta\gamma$ coincidences 49G10, 49K2
No delayed coincidences 49M26

Tm-n-γ chem 48K21
Tm-d-p 48K18

β_1^- ~10%	0.886	s		49F13
β_2^- ~90%	0.970	s	49G10,	49F13
	0.97	s		49S5
	0.98	s		48K21
γ_1	0.0839	sc		49F13
	α_K=0.4	α_L=2.75		49F13
		α_M=0.85		49F13
	0.0855	sc		49S5*
		K/L=0.71		49S5
	0.0827	sc		49G10
	α_K=0.4**			49G10
~25%	0.0826	s		49G3
	α_L~0.4, K/L~0.9			49G3
	0.0843	sc		49C15
	0.083			48K21

γ's of 0.20 and 0.44 (49G3) not found 49G10, 49F13

*α's given on assumption of only one β.

**Independent of decay scheme but definition not clear.

171
69 102

τ 680^{d} 48K21

β^- 0.10 s 48K21

No γ 48K21

Levels 0.113 Er^{171}
2.5$^{\mu s}$ delay
0.418
0.805

d of an Er 48K11

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	36	49P3
σ_t	46	42R2
	50	42B4

167 (70 97)

	<0.002%	49H8

168 (70 98)

	0.14%	49H8
	0.06	38D5, 41W9
	σ's	
(th n, γ) 33^dYb	18,300	46B25
	35,000	46A2

169 (70 99)

τ	33^d		46B9
	33.5		47I13
	32.5		48K18
K			46B9
γ sc	48I7	49C23	
	0.064		
	0.095	0.094	
	0.110	0.110	
	0.121		
	0.133	0.130	
	0.142		
	0.160		
	0.178	0.178	
	0.199	0.198	
	0.308	0.308	
Tm X-ray			46B9
No $\beta\gamma$ delay			49M26
Yb-n-γ	chem		48K21
	σ		46B25, 46A2

170 (70 100)

	3.03%	49H8
	4.21	41W9
Levels	0.084	Tm^{170}
	~2.5	Lu^{170}

171 (70 101)

	14.34%		49H8
	14.26		41W9
I	1/2	S	38S10
μ	0.45	S	38S11
Levels	?		Lu^{171}

172
70 102

	21.88%		49H8
	21.49		41W9
Levels	?		Lu^{172}

173
70 103

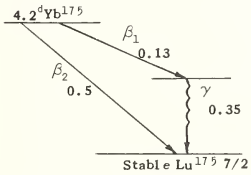
	16.18%		49H8
	17.02		41W9
I	5/2	S	38S10
μ	-0.65	S	38S11
q	+3.9		38S10

174
70 104

	31.77%		49H8
	29.58		41W9
	σ's		
(th n, γ) 4^dYb	74		46B25
	24		46A2

175
70 105

τ	4.2^d		46A2, 48K21
	4.1		46B9



β_1^-	0.13	a	46B9
β_2^-	0.50	a	46B9
	0.45	cc	46A2
γ	0.35	a	46B9
$\beta\gamma$ coincidences			46B9
Yb-n-γ	ms		47I8
	chem		48K21
	σ		46B25, 46A2

176
70 106

	12.65%		49H8
	13.38		41W9
	σ's		
(th n, γ) 1.8^hYb	6.7		46B25
(th n, γ) 1.8^hYb	4.5		46A2

177
70 107

τ	1.8^h		49M41
	2.4		46B9
	1.9		46A2
β^-	1.3	a	46B9
	1.2	cc	46A2
γ	0.15		49M41
	$0.13^{\mu s}$ delay		
No other γ follows the delay			49M41
Yb-n-γ	chem		48K21
	σ		46B25, 46A2

$^{?}_{70}$	$^{?}_{70}$	
τ 6^{S} 49D16	τ 50^{S} 49D16	
e^{-} ~0.200 49D16	γ 0.025 49D17	
Yb K X-ray 49D17	e^{-} 0.010-0.020 49D16	
	Yb L X-ray 49D17	
Yb-n-γ 49D17 σ(atomic) = 0.34	Yb-n-γ 49D17 σ(atomic) = 0.4	

Neutron Cross Sections for Natural Element			170 71 99				171 71 100			
$E_n = 0.025$eV			τ	2.1^d		49W12	τ	8.5^d		49W12
σ_a	108	49P3								
σ_t	99	42R2	K			49W12	K			49W12
	165	42B4								
			γ	~2.5	a	49W12	e^-	0.17	a	49W12
								~0.5	a	49W12
			e^-	0.1	a	49W12				
			K,L X-rays			49W12	K,L X-rays			49W12
			Tm-α-3n	chem, relσ		49W12	Tm-α-2n	chem, relσ		49W12
			Yb-d-2n, 3n			48W12	Yb-d-n, 2n, 3n			48W12
			Not produced by Yb-α, Tb-p			49W12	Not produced by Yb-α			49W12

172 ? 71 101?			172 ? 71 101?				172 ? 71 101?			
τ	3.40^d		49W12	τ	4.0^h		49W12	τ	500^d		49W12
K			49W12	β^+	1.2	a	49W12				49W12
β^+ ~20%	1.8	a	49W12	γ	Possibly annihilation		49W12	e^-	~0.1	a	49W12
									~0.16	a	49W12
K X-ray			49W12					K,L X-rays			49W12
Tm-α-n	chem, relσ		49W12	Tm-α-n	chem, relσ		49W12	Tm-α-n	chem, relσ		49W12
Yb-p-n	chem		49W12	Yb-p-n	chem		49W12	Ta-d			49W12
	d>60^{d}Hf		49W12						d of a Hf		49W12

173 ?
71 102?

τ	6.7^d		49W12
K			49W12
γ			49W12
e^-	0.13	a	49W12
	~0.6	a	49W12
K,L X-rays			49W12
Yb-p-n	chem		49W12
	d ~ 5^yHf		49W12

174 ?
71 103?

τ	160^d		49W12
K ~75%			49W12
β^- ~25%	0.6	a	49W12
γ			49W12
e^-	0.16	a	49W12
K,L X-rays			49W12
Lu-n-2n	chem		49W12
Hf-d-α	chem		49W12
Lu-d-p2n	chem,σ		49W12

175
71 104

	97.5%		39M3
I	7/2	S	35S3
μ	2.6	S	36G3
q	+5.9		36G3
Levels	0.35		Hf^{175}, Yb^{175}
	1.5		Hf^{175}
	σ's		
(th n,γ) 3.7^hLu	16		47S33
	27		46B25
	45		46A2
(10Mev p,n) 70^dHf	0.03		49W11
(19Mev d,2n) 70^dHf	0.05		49W11
(19Mev d,p) 3.7^hLu	0.044		49W12
(~1Mev n,γ) 3.7^hLu	0.10		49H28

176
71 105

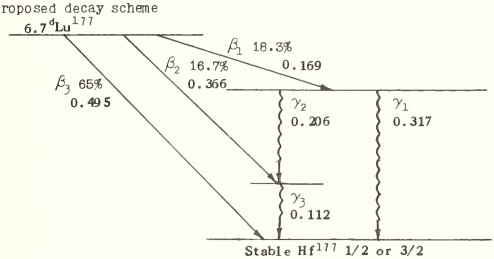
τ	3.75^h		49W12
	3.67		46A2
	3.7		46B9
β^-	1.04	a	48W12
	1.15	a	46B9
	1.25	cc	46A2
No γ			46B9
Lu-n-γ			46B9
	chem		48K21
	σ		47S33, 46B25, 46A2
Lu-γ-γ	σ		47D4
Lu-d-p	σ		49W12
Mass assignment from yield relative to 6.7^dLu in d-p and fast n-γ reactions			49W12, 46A2

	2.5%		39M3
τ	2.4×10^{10} ^{y}		39L13(47F7)
I	$\geqslant 7$	S	39S14
μ	3.8	S	39S14
q	+6-8		39S14
	σ's		
(th n,γ) 6.7^dLu	3640		47S33
	3600		46B25
	4400		46A2
(~1Mev n,γ) 6.7^dLu	0.30		49H28
(19Mev d,p) 6.7^dLu	0.04		49W12

K 67%			47F7
β^- 33%	0.40	a	43F2, 47F7
	0.22	a	39L13
γ 67%	0.26	a	47F7
K X-ray			47F7

$^{177}_{71}Lu_{106}$

τ	6.70^d		49W12
	6.8		46B9, 49C15
	6.6		46A2, 43F2
	7.0		49D5
Proposed decay scheme			49D5



No delayed $\beta\gamma$ coincidences (3×10^{-7} to 10^{-3} s)			49B9
Lu-n-γ	ms		47I8
	σ		47S33, 46A2, 46B25
	chem		48K21
Lu-d-p	σ		48W12
Hf-d-α			49W12

β_1^-	18.3%	0.169	s	49D5
β_2^-	~16.7%	0.366	s	49D5
β_3^-	65%	0.495	s	49D5
		0.46	a	49C15
		0.440	a	43F2
		0.52	a	46B9
		0.47	a	46A2
γ_1	weak	0.317	s	49D5
γ_2		0.206	s	49D5
		0.209	sc	49C15
		0.20	a	46B9
γ_3		0.112	s	49D5
		0.1131	sc	49C15

Level in Lu^{177} 0.15 Yb^{177}

Neutron Cross Sections for Natural Element	170 72 98	172 ? 72 100 ?
E_n = 0.025ev σ_a 103 49P3 157 49H2 σ_t 175 42L1 Resonance E_o ~1.0ev 49B2 This resonance formerly attributed to Zr. Graphs Available σ_t 0.02-1.5ev 49B2		τ >50^d 49W12 3.4^{d}Lu shown to grow from long-lived Hf parent, but presence of 67^{d}Hf prevents identification. 49W12 p 3.4^{d}Lu 49W12

172 ? 72 100 ?	173 ? 72 101 ?	174 72 102
τ 22.0^h 49W12 K or IT 49W12 e^- 0.12 49W12 0.22 49W12 K,L X-rays 49W12 Yb-α-2n,3n chem 49W12 Not p 6.7^{d}Lu 49W12	τ ~5^y 49W12 K 49W12 No e^- 49W12 K,L X-rays 49W12 Yb-α-n,2n,3n chem 49W12 Ta-d chem 49W12 p 6.7^{d}Lu 49W12	0.18% 44M2,49H3

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175 72 103			176 72 104			177 72 105		
τ	70^{d}	49W11		5.15% 5.30	49H3 44M2		18.39% 18.47	49H3 44M2
K γ Lu K, L X-rays	0.350 a α~0.4 1.5	49W11				I	1/2 or 3/2 S	35R1
			Levels	0.19 ? 2 ? ?	Ta^{176} Ta^{176} Lu^{176}	Levels	0.112 0.317 others ?	Lu^{177} Lu^{177} Ta^{177}
Lu-d-2n Lu-p-n Yb-α	chem,σ chem,σ	49W11 49W11 49W12						

178 72 106			179 72 107					
	27.08% 27.10	49H3 44M2	τ	19^{S}		46F1	13.78% 13.84	49H3 44M2
			IT			46F1	I 1/2 or 3/2 S	35R1
			γ	0.15 α>19, 0.19	sc K/L = 0.9 a	48H37 46F1		
Levels	?	Ta^{178}						
			Hf-n-γ			48H37,46F1		

180
72 108

35.44% 49H3
35.11 44M2

σ's
(th n,γ)46^{d}Hf 10 47S33

181
72 109

τ 46^d 47S33
47 48H55

β^- 0.405 s 49C11
0.460 s 48H55
0.41 s 49J5

$\beta\gamma$ delay of 20.1$^{\mu s}$ 48B14
$\beta\gamma$ delay of 22$^{\mu s}$ 48D5
~0.5 γ in parallel with delayed γ. 48D5
No $\beta\gamma$ delay between 3x10^{-8} s and 10^{-3} s other than 22$^{\mu s}$. 49M26

γ_2 and γ_5 follow the delay, γ_3 and γ_4 do not. 49H34

No delayed $\gamma\gamma$ coincidences 49W20
Hard γ's not in coincidence 48H55
$\beta\gamma$ and $\gamma\gamma$ coincidences 49M6

Delayed e$^-$'s of γ_2 and γ_5 in instantaneous coincidence. 49B9, 48B14

Hf^{181} produced by
Hf-n-γ σ 47S33
Ta-n-p ? 47N4

γ_1 0.087 s 49J5
Possibly in parallel with γ_3
γ_2 0.133 49H34
0.130 s 49C11
0.128 s 48H55
0.134 s 49J5
Highly converted. K/L < 1, exact value obscured by γ_3. 49C11
γ_3 0.136 49H34
0.134 s 49C11
γ_4 0.344 49H34
0.337 s 49C11
α~0.02, K/L = 4 49C11
22%* 0.347 s, K/L = 5 49J5
0.342 48H55
γ_5 0.480 49H34
78%* 0.471 s 49C11
α~0.02, K/L = 3 49C11
0.485 s, K/L = 5 49J5
0.472 s 48H55
* Relative values

Neutron Cross Sections for Natural Element

σ_s coh	6.1	49S12
σ_s bound	7.0	49S12
	$E_n = 0.025$ev	
σ_a	21	49P3
	36	49H2
σ_s	4.9	(48WH)
σ_t	26	47H25

Resonances

E_o	$\sigma_o\Gamma^2$	
4.1ev	~44	47H25
10.0	~25	47H25
13.0	~3	47H25
22	~18	47H25
37	~400	47H25

Graphs Available

σ_t	0.025-600ev	47H25, 47GIF
	See also	49H16
	0.02-1.5Mev	49B28, 50Ad

175
73 102

176
73 103

τ	8.0^h		49W13
K			49W13
No β^+			49W13
β^- or e^-	~1		49W13
γ	2	a	49W13
e^-	0.12	a	49W13
	0.18	a	49W13
K,L X-rays			49W13
Lu-α-3n	chem		49W13

177
73 104

τ	2.50^d		49W13
K			49W13
γ	~1.4		49W13
e^-	0.1	a	49W13
K,L X-rays			49W13
Levels	?		W^{177}
Lu-α-2n,3n	chem		49W13
Hf-p-n			49W13
Ta-d			49W13
d 2.2^hW			49W13

178
73 105

τ	15.4^d		49W13
β^- or e^-	1.5		49W13
No γ ?			49W13
Lu-α-n,2n	chem		49W13
Hf-p-n	chem		49W13

179
73 106

τ	$\sim 120^d$		49W13
e^-	0.120		49W13
Soft γ's			49W13
K X-ray or γ			49W13
Lu-α-n	chem		49W13
Ta-d-p3n	chem		49W13
Ta-p-p2n	chem		49W13
Hf-p			49W13
d 21^dW			49W13

180
73 107

τ	8.00^h	49W13
	8.2	3801
K		49W13, 3801
β^-	0.7	49W13
β^- or e^-	0.48	3801
γ	1.3	49W13
Hf K X-ray		49W13
Ta-n-2n		3801, 37P2
	chem	49W13
Ta-γ-n	threshold = 7.7	49M17
Ta-d-pn	chem	49W13
Ta-p-pn	chem	49W13
	threshold = 6	49B34

181
73 108

	100%		39D5, 48W9
I	7/2	S	33M1, 33G2
μ	2.1	S	35G1
q	~+6	S	43S15
Levels	? ?		Hf^{181}
$\beta\gamma$ delay of $20^{\mu s}$ in Hf^{181}			
	σ's		
(th n, γ) 117^dTa	21		47S33
	7		41H8(48WH)
(th n, γ) 16.4^mTa	0.034		47S33
(19Mev d, 2n) 140^dW	0.05		49W14

182
73 109

τ_1	16.4^m		48H37
	16.2		47S2
IT			48H37
γ	0.18	s	48H37
	K/L = 0.25		
β^-	0.2	a	47S33
16^m activity from Ta-fast n's with β^- of 0.6, e^-, and X			49W13
Ta-n-γ	chem, σ		47S33
	Not d 117^dTa		47S2

τ_2	117^d		47S33, 43Z1
	123.5		49C19
	99		40H8
β^-	0.25 ?	s	49B21
	0.53	s	47R1, 49B21
	0.50	s	47J1

γ	49C19	49B21	49G14	47R1
	0.0462			
	0.0583			
	0.0647			
	0.0668			
	0.0761		0.071	
	0.0837	0.082	0.084	
	0.0931			
	0.0992	0.098		
	0.107		0.103	
	0.109			
	0.112	0.112		
	0.118			
	0.123	0.122		
	0.138	0.132		
	0.150	0.141	0.151	0.15
	0.158	0.157		
	0.159	0.165		
	0.171	0.172		

49C19	49B21	49G14	47R1
0.178		0.180	
0.197	0.198		
0.212		0.209	
0.220	0.222	0.220	0.22
0.227			
	0.243		
	0.255		
0.261	0.264	0.261	
	0.290?		
0.301	0.299?		
0.307			
0.328	0.324		
	1.133	1.12	1.13
	1.219	1.19	1.22
	1.237	1.23	

1.13, 1.22, and 1.24 γ's most intense. 0.157, 0.165, and 0.222 γ's also prominent 49B21

βe^- coincidences 48S17
No delayed coincidences 49B9, 49M26

Ta-n-γ 3801
chem, σ 47S33
Ta-d-p 43Z1

Neutron Cross Sections for Natural Element				177 74 103		
σ_s coh	3.3	49S12		τ	2.2^h	49W13
σ_s bound	5.7	49S12				
	$E_n = 0.025$ev			K		49W13
σ_a	17.7	49P3				
	28.0	49H2				
				γ	~0.45 a	49W13
σ_s	5	(48WH)			1.2 a	49W13
σ_t	23	47H25		e^-	0.13 a	49W13
					~0.4 a	49W13
	Resonances					
E_o	$\sigma_o\Gamma^2$			K,L X-rays		49W13
4.0ev	~13					
7.4	~5					
18	~3,000	47H25				
45	~400					
180	~10,000					
	Graphs Available					
σ_t	0.014-5000ev	47H25, 47GIF		Ta-d-6n	chem	49W13
	See also 49H16			Ta-p-5n	chem	49W13
	0.023-4Mev	47GIF				
	0.023-1.4	50Ad				
					p 2.5^dTa	49W13

178 74 104		179 74 105			
<0.001% if stable form exists	49D7	τ_1	30^m 49W13	τ_2	21.0^d 49W13
		K	49W13	K	49W13
		K,L X-rays	49W13	e^-	0.1 49W13
		No γ, no e^-	49W13		~0.5 49W13
				K,L X-rays	49W13
		Ta-d-4n	49W13	Ta-d-4n	49W13
		Ta-p-3n	49W13	Ta-p-3n	49W13
				p 120^dTa	49W13

180
74 106

0.126%		48W9
0.122		46I1
0.135		46W3
0.16		48M27
0.143		49H3

181
74 107

τ	140^{d}		47W3
K			47W3
γ	1.83	a	47W3
e^{-}	0.07	s	47W3
	0.09	a	47W3
Ta K,L X-rays			47W3
Ta-d-2n			47W3
Ta-p-n	threshold < 4		49B34

182
74 108

26.31%		48W9
25.77		46I1
26.41		46W3
26.35		48M27
26.09		49H3
Levels	? ?	Re^{182}, Ta^{182}

183
74 109

τ	5.5^{s}		49D16
IT			49D16
e^{-}	0.080	a	49D16
W-n-γ			49D16

14.28%		48W9
14.24		49H3, 46I1
14.40		46W3
14.32		48M27
I	1/2 ?	34G2

184
74 110

30.64%		48W9
30.68		46I1
30.64		46W3
30.68		49H3, 48M27
Levels	?	Re^{184}
	σ's	
(th n,γ)73^{d}W	2.1	47S33

185
74 111

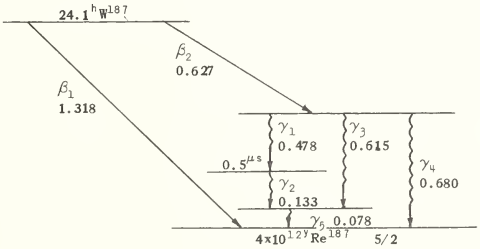
τ	73.2 d		48S18
	74.5		40F1
	76		49C7
β^-	0.428	s	48S24
	0.43	s	48P2, 48S18
No γ			48P2, 47C2
γ	0.134	sc	49C7
No delayed coincidences			49B9, 49M26
Re-d-α	chem		40F1
W-n-γ	chem		40F1, 40M5
	σ		47S33
W-n-2n	chem		40F1, 40M5
W-d-p	chem		40F1

186
74 112

	28.64%		48W9
	29.17		46I1
	28.41		46W3
	28.49		48M27
	28.85		49H3
Levels	?		Re^{186}
	σ's		
(th n, γ) 24^hW	34		47S33
	57		41H8 (48WH)
(~1Mev n, γ) 24^hW	0.066		49H5
Other fast n values			48WH, 49B4

187
74 113

τ	24.1^h		40F1
	24.0		40M5
	25.0		49C7



β_1	≥12%	1.318	s	49L10
	30%	1.33	s	48P2
		1.34	s	48H52
β_2	≥65%	0.627	s	49L10
	70%	0.63	s	48P2
		~0.65	s	48H52
γ_1		0.478	s	49L10
		0.462	s	48H52
γ_2		0.133	s	49L10
		0.138	s	49B23
		0.129	s	48H52
		$0.5^{\mu s}$ delay		
γ_3		0.615	s	49L10
		0.652	s	48H52
γ_4		0.680	s	49L10
		0.696	s	49B23
γ_5		0.078	s	49B23
		0.086	sc	41V1

β^- ~0.38, ≤23%; γ's 0.204, 0.767 also found 49L10

Half life of metastable state;

$0.53^{\mu s}$	49B9
$0.55^{\mu s}$	49M29

γ and soft β precede delay. Delayed radiation consists of e^- of 0.13-0.15 and γ of 0.1 48D5

W-n-γ	σ	47S33, 41H8
	E_γ(max) = 7.1	49K15
W-d-p	chem	48P2

Neutron Cross Sections for Natural Element						?		
	E_n = 0.025ev					τ	30^m	40C5
σ_a	84	49P3					30-55	44D9
σ_t	98	47GIF						
	Resonances							
E_o	Γ							
2.30ev		47GIF						
~27	~3	49G9						
Probably more than one		49G9						
	Graphs Available							
σ_s	0.015-10ev	47GIF,50Ad				W-p-n	chem	40C5,44D9
	See also	49H16						

182 75 107						183 75 108		
τ_1	64.0^h	49W14	τ_2	12.7^h	49W14	τ	240^d	49W14
K or IT		49W14	K or IT		49W14	K		49W14
No β^+		49W14	γ	0.110 sc	49W14	No β^+		49W14
γ	0.110 sc	49W14		0.129 sc		γ	0.081 sc	49W14
	0.129 sc			0.222 sc			0.252 sc	
	0.222 sc			0.250 sc			1.0 a	
	0.250 sc			0.346 sc		K,L X-rays		49W14
	0.346 sc			1.6 a				
	1.5 a		K,L X-rays		49W14			
K,L X-rays		49W14						
Ta-α-3n	chem,relσ	49W14	Ta-α-3n	chem,relσ	49W14	Ta-α-2n	chem,relσ	49W14
W-p-n	chem	49W14	W-p-n	chem	49W14	W-p-n	chem	49W14

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184
75 109

τ_1	50^d		49W14,46S6
	52		40F1
	54		40C5
No β^-			49W14
K or IT			49W14
γ	0.043	sc	49W14
	0.159	sc	49W14
	0.205	sc	49W14
	0.285	sc	49W14
	1.05	a	46S6
	0.75		47C2
	0.85	a	40F1
	1	a	49W14,40C5
K,L X-rays			49W14
Ta-α-n	chem,relσ		49W14
Re-n-2n	chem		40F1,49W14
W-p-n	chem		40C5,48W12
W-d-p			40F1

τ_2	2.2^d		49W14
K or IT			49W14
γ	0.043	sc	49W14
	0.159	sc	49W14
e^-	0.2	a	49W14
	1.1	a	49W14
K,L X-rays			49W14
Ta-α-n	chem,relσ		49W14
W-p-n	chem		49W14

185
75 110

	37.07%		48W9
I	5/2	S	31M1,31Z1
μ	3.3	S	38S10,38S9
q	+2.8		38S10
Level	0.75		Os^{185}

186
75 111

τ	92.8^h		47G1
	91		48C23,49G3
	90		40F1,39S5
β^- ~3%	0.64	s	49G3
~30%	0.95	s	49G3
~67%	1.09	s	49G3
	1.07	s	49B21
	1.068	s	49L6
	Fermi plot straight		
No γ's			47G1
γ	0.138	sc	49B21
	$\alpha_K = 0.029$, K/L = 0.4		
37%	0.132	sc	49G3
	0.214	s	49B21
2.3%	0.275	s,a	49G3
0.7%	0.7	a	49G3
No delayed coincidences			49B9
Re-n-γ	ms		47H7
Re-d-p	chem		47G1
W-d-2n	chem		40F1
Re-n-2n	chem		40F1
Re-γ-n	relσ		48P3
W-p-n	chem		40C5

187
75 112

	62.93%		48W9
τ	$4x10^{12y}$		48N1,48S25
I	5/2	S	31M1,31Z1
μ	3.3	S	38S10,38S9
q	+2.6	S	38S10
Levels	0.078		W^{187}
	0.211		
	$0.5^{\mu s}$ delay		
	0.680		
β^-	0.043	a	48N1

$^{188}_{75}Re_{113}$					
τ	18.9^{h}		47G1		
	18		40F1		
	16		48C23		
β^-	2.10	s	49B21		
	2.05	a	47G1		
γ	0.15	sc	49B21		
	0.154	sc	48C23		
	0.16	s	46M6		
	0.48	s	46M6, 49B21		
	0.64	s			
	0.95	s			
	1.40	s	49B21		
	1.43	s	46M6		
	1.39	a coin	48M1		
Re-n-γ	ms		47H7		
	chem		40F1		
Re-d-p	chem		47G1		

Neutron Cross Sections for Natural Element	183 76 107	184 76 108
$E_n = 0.025$ev σ_a 15 49P3 σ_s 11 37G1 σ_t 29 ce 47W8 Resonances E_o $\sigma_o\Gamma^2$ 6.5ev ~10 8.8 35 20 25 28 8 } 47W8 42 10 86 Graph Available σ_t 0.1-5000ev 47GIF,47W8		0.018% 37N3 Levels 0.043 ? Re^{184} 0.159 ? others?

185 76 109	186 76 110	187 76 111
τ 97^d 48K8 95 47G1 K 48K8,47G1 γ 0.75 a 48K8 K,L X-rays 48K8 γ/X~1 48K8 Re-d-2n chem 46G3,48K8 Os-n-γ chem,σ 48K8	1.59% 37N3 Levels 0.138 ? Re^{186} others?	1.64% 37N3

188
76 112

	13.3%		37N3
Levels	0.16 ??		Re^{188}
	others ?		

189
76 113

	16.1%		37N3
I	1/2	S	38K3

190
76 114

	26.4%		37N3
Level	0.25	?	Ir^{190}
	σ's		
(th n,γ)15^dOs	8		47S33

191
76 115

τ	15.0^d		48K8
	16.1		48S18
	17		41S7
β^-	0.142	s	48S18
	0.15	a	48M1
	0.35	a	41S7
	0.64	a Ir?	47W4
γ	0.039	sc	48S18
	0.127	sc	48S18
	K/L = 1.4		49S28
	0.129	sc	47C5
K?,L X-rays			48K8
$(X+\gamma)/\beta \sim 1$			48K8
Os-n-γ	chem		41S7, 40Z1
	σ		47S33
Os-fast n's, see Os^{193}			41S7

192
76 116

	41.0%		37N3
	σ's		
(th n,γ)32^hOs	1.6		47S33

193
76 117

τ	32^h		47G1,41S7
	30		47S33,40Z1
β^-	1.15	a	48M1
	0.95	a	47G1
	1.5	a	41S7
e^-	0.14	a	48M1
γ	1.58	a	48M1
	1.17	a	47G1
βe^- coincidences			48M1
No delayed $\beta\gamma$ coincidences			49B9
Os-n-γ	chem		47G1,41S7
	σ		47S33
Os-d-p	chem		47G1
Ir-d			47G1
Os-fast n's			41S7
32^h activity twice 15^d			41S7

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	464	49P3
	472	49H2
σ_t	430	47R6

Resonances

E_0	$\sigma_0\Gamma^2$	σ_0	Γ	
0.64ev	5-20			47R6
0.635		~530	0.25	47S31
1.27	5-20			47R6
1.35		~610	0.36	47S31
1.29			0.10	49G9
(assigned to Ir^{193})				49G9
5.2	~55			47R6
6.0				47S31
8.7	~50			47R6
25				47R6

Graphs Available

σ_t	0.055-15ev	47S31,47GIF
	0.22-1000ev	47R6,47GIF
	0.05-1.6ev	47W10

188
77 111

189
77 112

190
77 113

τ	10.7^d		47G1
e^- or β^-	0.091	a	47G1
γ	0.25	a	47G1
X-ray			47G1
Os-d-n	chem		47G1
Ir-n-2n			47G1
Not produced by Ir-n-γ or Ir-d			47G1

191
77 114

	38.5%	36S4
I	1/2 S	35V1
μ	negative	39S17
μ	$\frac{\mu(Ir^{191})}{\mu(Ir^{193})} = -0.92$	39S17
Levels	?	Os^{191}, Pt^{191}

σ's

(th n,γ)1.4^mIr	~250	47G6
(th n,γ)70^d+1.4^mIr	1000	47S33
(19Mev d,2n)3^dPt	~0.09	49W8
(38Mev α,3n)4.0^hAu	~1.5	49W8

192
77 115

τ_1	1.42^m		48H37
	1.5		37M4
IT ?			47G6
γ	0.0574	sc	49C1
	0.0555	sc	48H37

Softer γ's with ~ half above energy possibly due to 2-quantum transitions 47G6

Ir L X-ray 47G6

τ_2	70^d		47S33
	75		47G1
	68		48M14
β^-	0.67	s	47L6
	0.62	s	47J1

Conversion lines obscure end point.

γ	48H3	47L6	47C12	43D1
	0.137			
	0.208	0.209		
			0.269	
	0.296	0.295	0.294	
	0.308	0.307	0.306	0.307
	0.317	0.316	0.315	
		0.468	0.466	0.467
		0.488	0.477	
		0.591	0.586	
		0.607	0.601	0.603
		0.615	0.610	
			0.651	

Suggested level scheme		47C12
$e^-/\beta = 0.29$		47W5
0.32		48S17
E_γ per $\beta = 0.6$		48M14
βe^- coincidences		48S17
No delayed $\beta\gamma$ coincidences		49B9, 49M26
Ir-n-γ	ms	46R3
	σ	47S33
Ir-n-2n		37M4, 47G1
Ir-d-p	chem	48W1
Pt-d-α	chem	48W1

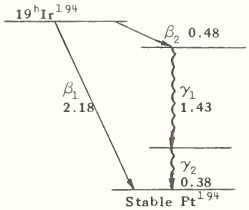
193
77 116

	61.5%		36S4
I	3/2	S	35V1
μ	$\frac{\mu(Ir^{191})}{\mu(Ir^{193})} = -0.92$		39S17
Levels	?		Os^{193}, Pt^{193}

σ's		
(th n,γ)19^hIr	130	47S33
(19Mev d,2n)4.3^dPt	~0.07	49W8
(38Mev α,2n)$18S^d$Au	~0.1	49W8
(38Mev α,3n)39^hAu	~1	49W8

194
77 117

τ	19.0^h		47G1
	20.7		47S33
	19.5		41W7



β_1^-	2.18	s	41W7
	2.1	a	47G1, 37M4
β_2^-	0.48	a$\beta\gamma$	48M14
γ_1	1.43	a coin	48M14
	1.35	s	43M4
	1.65	a	47G1
γ_2	0.38	a	47G1

See also Pt^{194}

$\gamma\gamma$ coincidences		48M14
No delayed $\beta\gamma$ coincidences		49B9
Ir-n-γ	ms	46R3
	σ	47S33
Ir-d-p	chem	48W1
Pt-d-α	chem	48W1

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	8.1		49P3
	13.3		49H2
σ_s	12		(48WH)
σ_t	16.6	ce	47H25

Resonances

E_o	$\sigma_o\Gamma^{-2}$	
11.5ev	~55	47H25
18.2	~30	47H25
100 ?		47H25

Graph Available

σ_t	0.004-5000ev		47GIF, 47H25

190
78 112

~0.006%		49D8

191
78 113

τ	3.00^d		49W8
K			49W8
γ	0.57	a, ac	49W8
	1.5	a	49W8
K, L X-rays			49W8
Ir-d-2n	chem, σ		49W8
Pt-n-2n	chem		49W8
d 1^dAu			49W8

192
78 114

	0.78%		47I12
	0.8		36S4
Levels	many low		Ir^{192}
	~2		Au^{192}

σ's

(th n, γ) 3.3^dPt	150 ?		47S33
40% may be due to Au^{199} growth			47S33
(19Mev d, p) 4.3^dPt	~0.05		49W8
(19Mev d, 2n) 4.0^hAu	~0.1		49W8

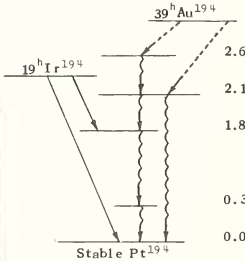
193
78 115

τ	4.33^d		49W8
	3.5		48H37
K			49W8
e^-	0.115	a	48M7, 49W8
	0.112	s	48H37
γ	0.126	sc	48H37
	K/L = 0.23		48H37
	0.18		49W8
	~1.5		49W8
K, L X-rays			49W8, 48M7
(K X-ray)/(L X-ray) ~0.5			49W8
$\gamma\gamma$ or γX coincidences			48M7
Pt-n-γ	chem		48M7, 49W8
Pt-n-2n			48H37, 49W8
Pt-d-p	chem		49W8
Ir-d-2n	chem, σ		49W8
Ir-α-pn	chem		49W8
d 16^hAu			49W8

194
78 116

	32.8%		47I12
	30.2		36S4

Possible levels

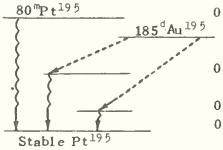


195
78 117

τ	80^m		41S8
	78		48H37
	87		48M33
IT^c			48H37
γ	0.337		48H37
	$\alpha = \infty$, K/L = 1.3		48H37
Hg-n-α	chem		41S8
Pt-d-p			41S8
Pt-fast n's			48H37, 41S8
Pt-γ			48M33
Not produced by Pt-n-γ			48H37, 41S8
No active daughter			48H37

	33.7%		47I12
	35.2		36S4
I	1/2	S	36J1, 37T3
μ	0.6	S	36S8

Levels



0.337
0.129
0.096
0.000

196
78 118

	25.4%		47I12
	26.6		36S4
Levels	0.358		Au^{196}
	0.688		
σ's			
(th n, γ) 18^hPt	1.1		47S33
(9Mev d, p) 18^hPt	16mb		42K7

197
78 119

τ	18^h		48W13, 37M4
	19		41S8
β^-	0.65	a	41S8
	0.72	a	41K5
No delayed $\beta\gamma$ coincidences			49B9
Pt-d-p	chem, σ		42K7
Pt-n-γ	chem		37M4
Hg-n-α	chem		41S8
Pt-n-2n			41S8
Pt-γ-n	rel σ		48W13

198
78 120

	7.23%		47I12
	7.2		36S4
σ's			
(th n, γ) 29^mPt	3.9		47S33
(~1Mev n, γ) 29^mPt	0.06		49H5
Other fast n values			49B4
(9Mev d, p) 29^mPt	29mb		42K7

199
78 121

τ	29^m		41S8
	31		37M4
β^-	1.8	a	41S8
Pt-d-p	chem, σ		42K7
Pt-n-γ	chem		37M4
	σ		47S33
Hg-n-α	chem		41S8
Not produced by Pt-fast n's			41S8
p 3.3^dAu			48M7, 37M4

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Neutron Cross Sections for Natural Element

σ_s coh	7.5	49S12
σ_s bound	~9	49S12
	E_n = 0.025ev	
σ_a	See Au^{197}	
σ_s	6.5	(48WH)
	7.6	49C21
σ_t	104	49C21, 44A2
	100	47B15
	99	47S31

Resonances

E_o	$\sigma_o\Gamma^2$	Γ	
4.8ev	600		47H25
4.8		0.15	49G9
4.6		0.5	48C24
>300			49H16

Graphs Available

σ_t	0.015-0.3ev	47GIF, 44A2
	0.01-0.13ev	47GIF, 47B15
	0.03-10ev	47GIF, 47S31
σ_a	0.03-3Mev	47GIF, 50Ad

$^{185-188}_{79}$

τ	4.3^m		49T13
K			49T13
β^+			49T13
α	5.2	ic	49T13
α/K capture	$\sim 10^{-4}$		49T13
Au-d	chem		49T13

$^{191}_{79}$ 112

τ	$\sim 1^d$		49W8
K			49W8
Pt-d-3n	chem		49W8
Ir-α-4n	chem		49W8
	p 3.0^dPt		49W8

$^{192}_{79}$ 113

τ	4.0^h		49W8
K			49W8
β^+	1.9	a	49W8
γ	2-3	a	49W8
e^-	0.4	a	49W8
	1.5	a	49W8
K, X-ray			49W8
Pt-d-2n	chem		49W8
Ir-α-3n	chem		49W8

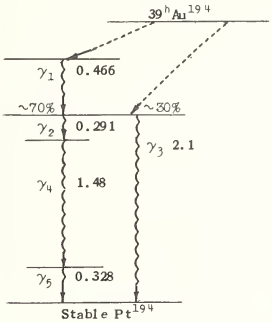
$^{193}_{79}$ 114

τ	15.8^h		49W8
K			49W8
e^-	<0.2	a	49W8
K, L X-rays			49W8
Pt-d-3n	chem		49W8
Ir-α-2n	chem		49W8
	p 4.3^dPt		49W8

194
79 115

τ	39.5^h	49W8
	39	49S17

Proposed decay scheme 49S17



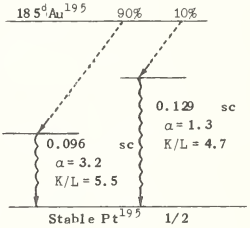
γ_1	weak	0.466	sc	49S17
γ_2	70%	0.291	sc	49S17
		$\alpha = 0.054$, K/L = 2		49S17
γ_3	30%	2.1	s	49S17
γ_4		1.48	sc	49S17
		$\alpha = 0.0026$		49S17
γ_5		0.328	sc	49S17
		$\alpha = 0.19$, K/L = 2		49S17
β^+	3%	1.8	a	49W8

Ir-α-3n	chem	49W8
Pt-d-2n, 3n	chem	49W8
Pt-p-n	chem	49S17

195
79 116

τ	185^d	49W8
	180	49S17

Proposed decay scheme 49S17



γ	0.19	a	49W8
	1.6	a	49W8

Ir-α-2n	chem	49W8
Pt-d-n	chem	49W8
Pt-p-n	chem	49S17

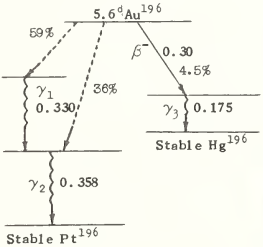
196
79 117

τ_1	14.0^h	49W8
	13	37M4

K or IT	49W8
X-ray	49W8
e^-	37M4

Au-n-2n	chem	37M4, 49W8

τ_2	5.55^d
	5.60



β^-	4.5%	0.30	s	49S17
		0.34	a	49W8
γ_1	59%	0.330	sc	49S17
		$\alpha = 0.087$		
		K/L = 1.7		49S17
γ_2	95%	0.358	sc	49S17
		$\alpha = 0.087$		
		K/L = 1.7		49S17
γ_3		0.175		49S17
		$\alpha = 0.15$, K/L = 3.4		49S17
γ		1.6	a	49W8

Pt-d-n, 2n	chem	49W8, 40L2
Au-n-2n		49W8, 49S17
Pt-p-n		49S17
Au-γ-n	relσ	48W13
threshold = 8.0		49S17

197
79 118

τ	7.4^s		48F12, 47F4
	7.5		45W2
IT			45W2
γ	0.273	sc	48H24
	0.25	a	45W2

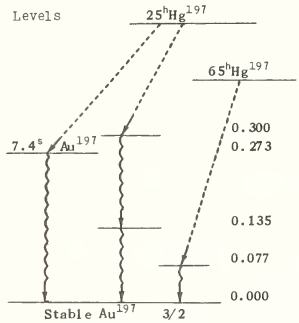
e^-e^- coincidences in 7.4^s activity but second γ not found 48H24

Au-γ-γ			45W2
Au-n-n			45W2
d 25^hHg			47F4

100% 35D2

I	3/2	S	39E3
μ	0.195	S	39E3

Levels



25^hHg^{197} goes to level in Au^{197} with
$\tau = 8\times10^{-9}$ 49D22
7×10^{-9} 49M42

This level does not appear in decay of Pt^{197} 49D22

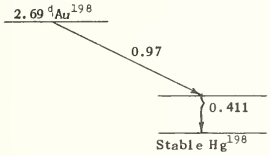
Levels in Au^{197} which combine with 7.4^s level 0.25 45W2
1.22
1.68
2.15
2.56
2.97

σ's

(th n,γ) 2.7^dAu	96	47S33
($\sim$1Mev n,γ) 2.7^dAu	0.12	49H5
Other fast n values		49B4, 48WH
(fast n,γ)	graph	47GIF, 50Ad

198
79 119

τ 2.69^d 49S18, 49S2



Half life of 0.411 γ $<4\times10^{-9}$ s 49D12
$<3\times10^{-9}$ 49B39

No $\beta\gamma$ coincidences delayed from 3×10^{-7} to 10^{-3} s 49B9

Au-n-γ	σ		47S33
E_γ(max) = 7.3			49K15
Pt-p-n	chem		49S17
Au-d-p	chem		48P2
Hg-n-p	chem		41S8

K $\leqslant$0.4% from search for Pt X-ray 49R6

β^-	0.966	s	49L7
	0.956	s	49L6
	0.975	s	49S17
	0.955	s	49D20
	0.970	s	49S33
γ	0.4112	cryst	48D3
	0.411	sc	49S17, 49S19
	0.415	sc	49S33, 49S18
	0.410	sc	49D20
	0.408	sc	48P2, 49L7

	α_K	α_L	α_M	
	0.028	0.013	0.003	49S17
	0.026	0.012	0.003	49S33
	0.03	0.01	0.003	49S19

α = 0.048 K/(L+M) = 2.7 49S18

γ 18% 0.070 a 49S17
involved in $\gamma\gamma$ coincidences

γ's of 0.157, 0.208 found 49L7, 48D3
Not found 49S17, 49S18, 49S19
See Au^{199}

$\gamma\gamma$ coincidences found 48M35, 49S17
Not found 48J7, 49S19

No $\beta\gamma$ angular correlation 49G21, 49F16

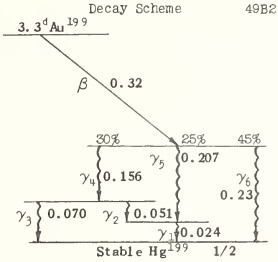
Decay energy of 0.79 found by calorimetric measurement 47C13

γ's of 0.67 and 1.09 found in low intensity 49C24

199
79 120

τ	3.3^{d}	37M4

Decay Scheme 49B21



β^-	0.32	s	49B21
	0.32	a	49M32
	0.38	a	48M7
γ_1	0.024	sc	49B21
γ_2	0.051	sc	49B21
γ_3	0.070	sc	49B21
γ_4	0.156	sc	49B21
Most strongly converted K/L~1			49B21
γ_5	0.207	sc	49B21
γ_6	0.230		49B21
K line overlaps L line of 0.156γ. No L line.			49B21

Pt-n-$\gamma\beta$	chem	49B21
Hg-n-p	chem	41S8
d 31^{m}Pt		37M4
Not p 43^{m}Hg		49M32

$\beta\gamma$ coincidences independent of β energy. $\gamma\gamma$ coincidences observed 49M32

No delayed coincidences 49B9

200 ?
79 121?

τ	48^{m}		41S8
β^-	2.5	a	41S8

Hg-n-p	chem	41S8,42M3
Tl-n-α		42M3

Neutron Cross Sections for Natural Element

	E_n = 0.025ev		
σ_a	349		49P3
	360		49H2
σ_t	400		46H26, 45B13
	Resonance		
E_o			
-2.0 ev			46H26
	Graphs Available		
σ_t	0.01-0.25ev		47GIF, 45B13
	0.01-75ev		47GIF, 46H26
See also			49H16

?

τ	0.7^m		49T13
α	5.7	ic	49T13
Au-d			49T13
chemistry suggests Hg			49T13

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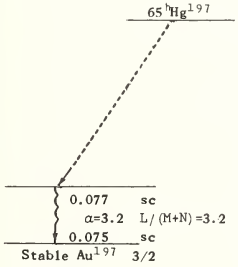
80 116

	0.16%		49H3
	0.155		47I14
	0.15		37N2
Level	0.175		Au^{196}
	σ's		
(pile n,γ)		3100	47I14

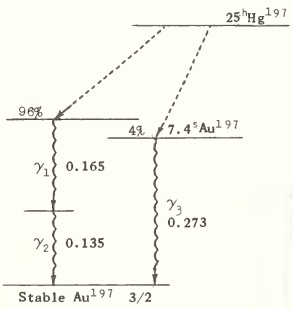
197
80 116

τ_1	65^h		48H24
	64		43F1, 42D8



	0.077	sc	48H24
	α=3.2	L/(M+N)=3.2	48H24
	0.075	sc	42H4
Au K X-ray			43F1
Au-d-2n	chem		43F1
Hg-n-2n	chem		43F1
Au-p-n			48H24, 42D8

τ_2	25^h		48H24, 42D8
	23		43F1



$25^h Hg^{197}$ goes to level in Au^{197} with τ = 8×10^{-9} 49D22
7×10^{-9} 49M42
This level does not appear in decay of Pt^{197} 49D22
e^-e^- coincidences in 7.4^s activity but second γ not found 48H24

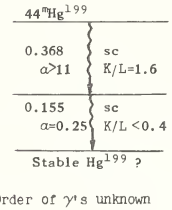
γ_1	0.165	sc	48H24
	0.161	sc	42H4
	K/L < 1		42H4
	0.157	sc	41V2
γ_2	0.135	sc	48H24
	0.130	sc	42H4
	K/L < 1		42H4
	0.125	sc	41V2
γ_3 4%			47F4, 48F12
	0.273	sc	48H24
	7.4^s delay		
γ weak	0.38	a	47F4
Au K X-ray			43F1
Hg-n-γ	σ		47I14
Hg-n-2n	chem		43F1
Pt-α-n			41S8
Au-d-2n	chem		43F1
Hg-d-p	chem		40K8
Au-p-n			42D8, 48H24

198
80 118

10.02%		49H3
10.12		47I14
10.1		37N2
Levels	0.411	Tl^{198}, Au^{198}
	1.3	Tl^{198}
σ's		
(9Mev d,p) $44^{m}Hg$	0.07	42K7

199
80 119

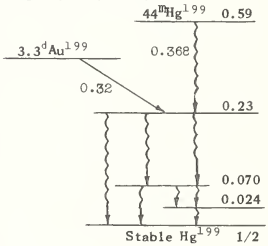
τ	43.5^{m}	48H48
	44.4	48M33
	43	37M4,37H4



Order of γ's unknown		48H37
Hg K X-ray		43F1
Hg-fast n's	ms	49B13
	chem	48H48,43F1,37M4
Hg-γ		45W2,48M33
Pt-α-n		41S8
Hg-d-p	σ	42K7
	Not d $3.3^{d}Au^{199}$	49M32

	16.92%		49H3
	17.01		47I14
	17.0		37N2
I	1/2	S	31S3,32S1
μ	0.547	S	40M10

Possible level scheme



See also Tl^{199}

σ's		
(pile n,γ)	2500	47I14

200
80 120

	23.10%	49H3
	23.21	47I14
	23.3	37N2
Level	~0.4	Tl^{200}
	1.6 ?	
σ's		
(th n,γ)	<60	47I14
Hg-γ-n		49H17
threshold = 6.25		49H17
Hg-n-γ		49K15
E_{γ}(max) = 7.1		49K15

201
80 121

	13.22%		49H3
	13.5		47I14
	13.2		37N2
I	3/2	S	31S3,32S1
μ	-0.607	S	40M10
Level	~0.2		Tl^{201}
σ's			
(th n,γ)	<60		47I14

202
80 122

	29.72%	49H3
	29.66	47I14
	29.6	37N2
Level	0.40	Tl^{202}
σ's		
(th n,γ) $44^{d}Hg$	2.5	47S33
(th n,γ)	<60	47I14

203
80 123

τ	43.5^{d}		48S30
	51.5		43F1
	50		41S8

$43.5^{d}Hg^{203}$

0.208	s	49S16
0.205	s	48S30
0.279	sc	49S16
α=0.27	K/L=3	49S16
0.286	sc	48S30
α=0.24	K/L=3	48S30
0.265	sc	48K25

Stable Tl^{203} 1/2

$\beta\gamma$ coincidences		49S16
No X-ray		43F1
No delayed coincidences		49B9, 49M26,49D22
See also Tl^{203}		
Hg-n-γ	ms	49S16,47I14
	chem	43F1
	σ	47S33
Hg-n-2n	chem	43F1
Hg-d-p	chem	40K8
Tl-n-p		42M3
	No active Tl daughter	43F1

204
80 124

6.84%		49H3
6.69		47I14
6.7		37N2

σ's

(th n,γ)$5.5^{m}Hg$	0.3	47S33
(~1Mev n,γ)$5.5^{m}Hg$	0.88mb	49H5
(9Mev d,p)$5.5^{m}Hg$	13.5mb	42K7

205
80 125

τ	5.5^{m}		40K8,42M3
β^-	1.62	a	40K8

Hg-n-γ		43F1
	σ	47S33
Tl-n-p		42M3
Pb-n-α		42M3
Hg-d-p	σ	42K7
	Not produced by	
Hg-fast n's		42K7

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	3.27	49P3
	3.29	49H2
σ_s	14	37G1
σ_t	11.6	See graphs
	Resonances	
E_o	230	48R7
	~990	
	~4300	
	$E_n = 3$Mev	
σ_t	5.2	48B28
	Graphs Available	
σ_t	0.015-10,000 ev	47W8, 47GIF, 50Ad

198 — 81 117

τ	1.8^h		4901
K			4901
γ	1.3	a	4901
e^-	~0.4	a	4901
L X-ray			4901
K X-ray obscured by e^-'s and γ's			4901
Au-α-3n	chem		4901
	d ~ 25^mPb		49N5, 49K11
Probably d 7^mBi			49N5

199 — 81 118

τ	7^h		4901
K			4901
γ	>1	a	4901
e^-	0.5	a	4901
L X-ray			4901
K X-ray obscured by e^-'s and γ's			4901
Tl activities of 10.5^h and 44^h from Hg-d (40K8) are possibly mixtures of Tl^{198} and Tl^{201}			
Au-α-2n	chem		4901
	d ~ 80^mPb		49N5
	d 25^mBi		49N5

200 — 81 119

τ	27^h		4901
K			4901
γ	~0.35	a	49N5
	1.6	a	49N5
e^-	~0.4	a	4901
	~0.35	a	49N5
Au-α-n	chem		4901
	d 18^hPb		49N5
	d 35^mBi		49N5

201 — 81 120

τ	72^h		49N5
K			49N3
γ	~0.21	s	49N5
	α ~ 0.6		49N5
K X-ray			49N5
	d ~ 2^hBi and 60^mBi		49N5
	d 8^hPb		49N5

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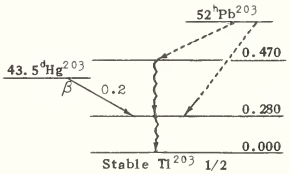
202
81 121

τ	11.8^{d}		41F4
	13		42M3,40K8
K ?			42M3,40K8
γ	0.40	a	42M3
X-ray	~0.068	a	42M3
Tl-n-2n	chem		41F4
Hg-d-2n	chem		40K8

203
81 122

	29.52%		49H3
	29.46		48W9
	29.1		38N3
I	1/2	S	31S2,32J2
μ	1.596		49P0
		I	49P7,49P8

Possible relationships 49S16



	σ's		
(th n,γ)2.7^{y}Tl	7.5		47S33

204
81 123

τ	2.7^{y}		45V1
	3.5		41F4
β^{-}	0.783	s	49S36
	0.770	s	47P10
	0.87	cc	41F4
No γ			41F4
No delayed $\beta\gamma$ coincidences			49B9
β spectrum has forbidden shape			49S36
Tl-d-p	chem		41F4,40K8
Tl-n-γ			41F4
Tl-n-γ	σ		47S33
Tl-γ-n (n's observed)			49H17
threshold = 7.5			49H17

205
81 124

	70.48%		49H3
	70.54		48W9
	70.9		38N3
I	1/2	S	31S1,32J2
μ	1.612		49P0
		I	49P7,49P8
	σ's		
(th n,γ)4.23^{m}Tl	0.11		47S33
	0.07		41M6
(9Mev d,p)4.23^{m}Tl	28mb		42K7

206
81 125

τ	4.23^{m}		40F4
	4.4		40K8
β^{-}	1.65	a	41F4
	1.77	a	40K8
	1.8	a	46B7
No γ			41F4
Tl-n-γ	chem		41F4
	σ		47S33,41M6
Tl-d-p	chem		40K8,40F4
	chem,σ,f		42K7
Pb-γ-p	chem		46B7
	d 4.85^{d}Bi^{210} (RaE)		47B6

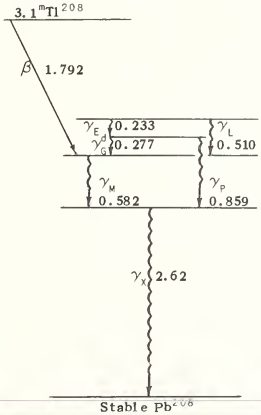
AcC" 207
81 126

τ	4.76^{m}		39S11,31IR
	4.77		40F2
β^{-}	1.47	a	39S12
	1.45	a	49E3
γ in AcC + AcC"			
0.5%	0.870		41S16
Pb-n-p	chem		40B2
Pb-γ-p	chem		46B7
4.5^{m} activity found probably mixture of Tl^{206} and Tl^{207}			46B7
	d 2.16^{m}Bi^{211} (AcC)		

ThC"
$^{208}_{81}$ 127

τ 3.1^m 31IR

Proposed decay scheme. 48R12



β^- complex	1.792	s	48M29	Shape of β spectrum consistent
	1.805	s$\beta\gamma$	48F9	with proposed decay scheme 48R12
	1.72	s$\beta\gamma$	47S37	Possible weak high energy β 48M29

γ	E_d	G	L	M	P	X	
$h\nu$	0.233	0.277	0.510	0.582	0.859*	2.62	32E1
			0.51	0.57		2.58	47J5
Rel γ intensities			0.51	1.01		1.00	47J5
% K e$^-$'s per disintegration		2.50	1.77	1.49†	0.26	0.18	48M29
		2.73	2.26	1.75†	0.26	0.23	39F4
	0.20	3.2	1.7	1.5 †·	0.30	0.35	32E1
% L e$^-$'s per disintegration		0.35		0.38			48M29
		~0.42		0.36			39F4
		0.65					32E1

† Includes L conversion of γ_L
* Assigned to ThC" 48M29

3.2Mev γ not found 48B27,46B36

d 60.5^{m}Bi^{212} (ThC)

$^{209}_{81}$ 128

τ	2.2^m		48H10
β^-	1.8	a	48H10

d 47^{m}Bi^{213} 48H10
p 3.3^{h}Pb 44F11,48H7

RaC"
$^{210}_{81}$ 129

τ	1.32^m		31IR
	1.3		37D3
β^-	1.8	cc	38L7
	1.9	a	37D3
γ	~5	a	37D3
γ's in Ra (C+C'+C"+D)			
	3.1	cc	37N4
	4.0	cc	37N4
	4.9	cc	37N4

d 19.7^{m}Bi (RaC)
p 22^{y}Pb (RaD)

Neutron Cross Sections for Natural Element			198 82 116			199 82 117		
σ_s coh	11.5	49S12	τ	$\sim 25^m$	49K11,49N5	τ	$\sim 80^m$	49N5
σ_s bound	11.6	49S12						
	$E_n = 0.025$ev					K		49N5
σ_a	0.19	49P3						
	0.18	49H2						
	0.12	49W22						
σ_t	8.5 ce	See graphs						
	$E_n = 0.4$-100ev							
σ_t	~ 13	See graphs						
	Resonances							
E_o	350kev	49B31						
	525							
	750							
	Graphs Available							
σ_t	0.003-10ev	50Ad,47GIF,47H28	Tl-p		49K11			
See also		49H16						
	0.2-14Mev	47GIF						
	1-300 Mev	50Ad						
	0.2-1.6 Mev	50Ad,49B28,49B31				d 25^mBi		49N5
			p 1.8^hTl		49N5,49K11	p 7^hTl		49N5

200 82 118			201 82 119			202 82 120		
τ	18^h	49N5	τ	8^h	49N5		$< 0.0004\%$	49D7
				~ 5	46H15	τ	$> 500^y$	49N5,47T3
K		49N5	K		46H15			
			γ		46H15			
			e^-		46H15			
			Tl-d-4n		46H15			
	d 35^mBi	49N5		d 62^mBi and 2^hBi	49N5			
	p 27^hTl	49N5		p 72^hTl	49N5			

203
82 121

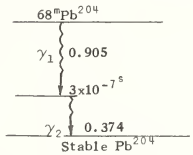
τ	52^h		46B7,41F4
	54		40K8,42D8
K			42M3
γ	0.270	s	44L1,42M3
	0.470	s	44L1,42M3
	~1.45	a	40K8,41F4
Pb or Tl K X-ray			42M3,40K8

See Tl^{203} for probable decay scheme

Tl^{203}-d-2n		47T3
Tl-d-2n	chem	41F4,46H15
threshold > 7		40K8
Pb^{204}-n-2n		47T3
Tl-p-n		42D8
Pb-n-2n		42M3
Pb-γ-n		46B7

204
82 122

τ	68^m		42M3
	65		41F4
	69		46B7
IT			42M3,41F4,47T3



γ_1	0.905	s	49S34
	$\alpha = 0.10$, K/L ~ 1.5		
	0.9	a	42M3
	1.1	a	41F4
γ_2	0.374	s	49S34
	$\alpha = 0.05$, K/L ~ 2		
	$\tau = 3\times10^{-7}$ s		
More than one e^-			40K8

1.37%		48W9
1.5		38N4

68^mPb^{204} produced by

Tl-d-n	chem	41F4
Tl-d-3n		47T3
Pb-n-n		42M3,39D3
Pb-γ		46B7
d 12^hBi		49N3,47T3
d 4^hPo		49K11

205
82 123

206
82 124

25.15%		48W9
23.6		38N4
Levels	? Bi^{206},Po^{210} (RaF)	
	σ's	
(α,3n)5.7^hPo	1-2	47T3
Pb-γ-n	n's observed	49H17
threshold = 6.9		49H17

207
82 125

21.11%			48W9
22.6			38N4
I	1/2	S	32K1,38C3
μ	0.588	I	49P11
Levels	0.87 ?		Tl^{207}(AcC")

$^{208}_{82}$ 126

	52.38%	46W9
	52.3	38N4
Levels	2.62	Tl^{208}(ThC")
	3.2	
	3.5	
	3.7	
	σ's	
(th n,γ)3.3^{h}Pb	~1mb	42M3
	0.45mb	43L4
(~1Mev n,γ)3.3^{h}Pb	1.8mb	49H5
(9Mev d,p)3.3^{h}Pb	14.1mb	42K7
(40Mev α,pn)5^{d}Bi	8mb	47T3
(40Mev α,2n)138^dPo^{210}	0.4	47T3
(40Mev α,3n)5.7^hPo^{207}	1-2	47T3

$^{209}_{82}$ 127

τ	3.32^h		41F4
	2.75		40K8
β^-	0.68	s	47R1
	0.71	s	44L7
	0.75	a	42M3
	0.70	a	41F4,40K8
No γ			44L7
Pb-d-p	chem		41F5,41F4
	chem,σ,f		42K7
Pb-n-γ	chem		42M3
Bi-n-p	chem		42M3
	d 3x10$^{-6\,s}$$Po^{213}$		47E3,47H2, 49M16

RaD $^{210}_{82}$ 128

τ	22^y		31IR
β^-	0.026	s	39L14
	0.029	s	46S1
γ ~10% *	7.3kev		46T4
~0%	18-19		
~1%	23.2		
0.4%	32		
0.2%	37		
0.2%	43		
2.8%	46.7 α_L = 2.9		
e^- 1%			37R5
L X-ray ~30%			44T4
K X-ray ~1%			44T4

46T4 gives summary of work of Curie Laboratory 1942-1945. For further details see 46F7, 45T6, 44M8, 44T4, and 43O4.

* % of disintegrations from absorption and conversion e^- measurements.

γ (7)*	7.8kev	pc	49C4
(0.4)	25.8	pc	
(3)	46.0	pc	
L X-ray (33)			49C4

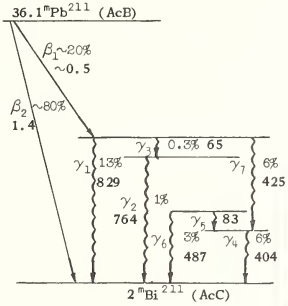
* Relative intensities of unconverted γ's

γ	47kev	
	$\alpha_L:\alpha_M:\alpha_N$ = 1:0.26:0.08	50C1
	α_L = 16	50C1

d 1.3^mTl^{210} (RaC")
d 1.5x10$^{-4\,s}$$Po^{214}$ (RaC')
p 5.0^dBi^{210} (RaE)

AcB
211
82 129

τ 36.1^{m} 39S11



γ energies in kev

β_1^- ~20% ~0.5 39S12

β_2^- ~80% 1.39 39S12

γ energies s, sc 38C4,40F2,42S9
γ intensities 42S9
% of disintegrations calculated from number of conversion e^-'s, assuming quadrupole transitions 42S9

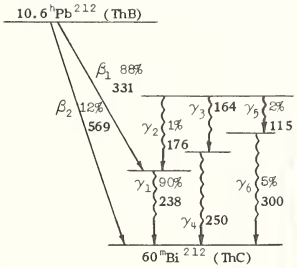
0.05±0.02 quanta of 829kev γ per disintegration 44M7

d 1.8x10^{-3} ^{s}Po^{215} (AcA)
p 2^{m}Bi^{211} (AcC)

ThB
212
82 130

τ 10.6^{h} 31IR

Proposed decay scheme 46S23



γ's sc 37S7,38S12
additional γ's at 113 and 135 37S7,38S12

Intensities 32E1,46S23

d 0.16^{s}Po^{216} (ThA)
p 60^{m}Bi^{212} (ThC)

All energies in kev

β_1^-	88%	331	s	48M30
		355	s	48F9
β_2^-	12%	569	s	48M30
		589	s	48F9
γ_1		238	s	44S30
		Hρ(F)* = 1384	K/L = 7.1	44S30
		1381	K/L = 8.3	39A6
		1386	K/L = 6.7	32E1
		K conv e^-/disint.	0.288	48F9
			0.313	48M30
		Hρ(I)** = 1750		44S30
		1747		39A6
		1751		32E1
Bi K X-ray				28M3

* F is K conv line
** I is L conv line

RaB
214
82 132

τ 26.8^{m} 31IR

β^-	0.72		41C1
	0.65		33Sar
γ kev	52.8	sc	44S30
1.6 γ's per disintegration			43T3
	241.0	sc	44S30
	257.8	sc	
	294.2	sc	
	350.9	sc	

γ values in close agreement with above 34E1,41H9

d 3.05^{m}Po^{218} (RaA)
p 19.7^{m}Bi^{214} (RaC)

Neutron Cross Sections for Natural Element			
σ_s coh	10.1		49S12
σ_s bound	~10		49S12
	E_n = 0.025ev		
σ_a	<0.01		46M20
σ_s	~9		(48WH)
σ_t	6.6	ce	See graphs
	E_n = 1Mev		
σ_t	~4.5		See graphs
	Graphs Available		
σ_t	0.015-100ev		48H46,47GIF,50Ad
See also			49H16
	0.020-0.50Mev		49B31,50Ad
	0.020-1.4Mev		50Ad
	0.02-14Mev		47GIF

<198 83			
τ	1.7^m		49N5
	2		48T1
α	6.2	ic	49N5
Pb-d			49N5,48T1
Pb-p		chem	49N5

198 83 115			
τ	7^m		49N5
	9		48T1
K ?			48T1
α	5.83	ic	49N5
	~5.5	ic	48T1
$K/\alpha = 2\times10^3$			49N5
Pb-d		chem	49N5,48T1
Pb-p		chem	49N5
	p 25^mPb		49N5
Probably	p 1.8^hTl		49N5

199 83 116			
τ	25^m		49N5
	27		48T1
K			49N5
α	5.47	ic	49N5
	~5.5	ic	48T1
$K/\alpha = 8\times10^3$			49N5
Pb-d		chem	49N5,48T1
Pb-p		chem	49N5
	p 80^mPb		49N5
	p 7^hTl		49N5

200 83 117			
τ	35^m		49N5
K			48T1
No α observed			49N5
Pb-d		chem	49N5
	p 18^hPb		49N5
	p 27^hTl		49N5

201 ? 83 118 ?				201 ? 83 118 ?				202 83 119			
τ	62^m		49N5	τ	$\sim 2^h$		49N5	τ	2^h		49K11
	~ 100		48T1								
K			48T1	K			49N5	K			49K11
α	5.15	ic	49N5								
	~ 5.5	ic	48T1								
$K/\alpha = 3\times10^4$			49N5								
Pb-d	chem		49N5, 48T1	Pb-d	chem		49N5				
Pb-p	chem		49N5	Pb-p	chem		49N5				
	p 8^hPb		49N5		p 8^hPb		49N5		d 40^mPo		49K11
	p 72^hTl		49N5		p 72^hTl		49N5				

203 83 120				204 83 121				205 83 122			
τ	12^h		49N5	τ	12^h		47T3	τ	$\sim 14^d$		49K11
K			49N5	K			47T3	K			49K11
				e^-	0.2	s, a	47T3	γ	1.7		49K11
				weak	~ 0.8	s, a	47T3				
				γ	0.217	s	49S34				
				Pb^{204}-d-2n			47T3				
				Tl-α-3n			47T3				
	d 37^mPo		49K11		d 4^hPo		49K11		d 1.5^hPo		49K11
	p 52^hPb		49N5		p (4%) 68^mPb		47T3				

889592 O - 50 - 32

206
83 123

τ	6.4^d		40K8
K			47T3
No β^+			47T3
γ		sc	49S34
0.182	0.470	0.880	
0.234	0.505	0.889	
0.260	0.536	1.020	
0.346	0.590	1.097	
0.996	0.803	1.720	
γ	0.4	ac	47T3
	1.1	ac	47T3
	1.1		41F4
γ with $1.67 < E < 2.3$			49D23
L X-ray			47T3
Tl-α-3n	chem		47T3
Pb-d-2n	?		41F4,40K8
Pb^{207}-d-3n	chem		40K8
d 9^dPo			47T1

207
83 124

No activity found from bombardment of Tl, Pb, Bi with 20Mev d and 40Mev α — 47T3

208
83 125

τ	$< 30^s$	49N3
	or very long	49N3
	$> 100^y$	47T1

209
83 126

	100%		38N3
I	9/2		28B1
μ	3.45	S	40W8
q	-0.4	S	36S6
σ's			
(th n,γ)5^dBi	0.015		47S33
(1Mev n,γ)5^dBi	0.003		49H5
(α,2n)7.5^hAt	f		49K10
(α,3n)8.3^hAt	f		49K10
(9Mev d,p)5^dBi	6.6mb		42K7
(20Mev d,p)5^dBi	0.13		47T1
threshold = 5.3	f	49K10,	47T17
(20Mev d,n)138^dPo	0.036		47T1
threshold = 6.5	f	49K10,	47T17
(20Mev d,3n)3^yPo	1.1		47T1
threshold = 12.5	f		49K10
(9Mev d,n)138^dPo	1.2mb		42K7
(γ,n)	f		49M17
threshold = 7.45, n's detected			
(20Mev γ,n) no activity			48M33

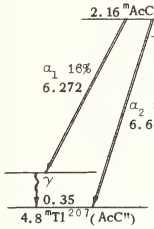
RaE
210
83 127

τ_1	long		49N3
α	5.02		49N3
Bi-n-γ			49N3
p 4^mTl			49N3
τ_2	4.85^d		46S22
	5.15		44H7
	5.0		31IR
β^-	1.17 s		39F2,40N4
unallowed shape			49L6,40N4, 49L3,49M18
shape at low energies			49W6
No γ			47L22,36G2
Bremsstrahlung studied			47S29
No βe^- coincidences			48H42
$\alpha \sim 5 \times 10^{-5}$%			47B6
Pb^{208}-α-pn	chem,σ		47T3
Bi^{209}-d-p	chem,σ		47T3
Bi-n-γ	σ		47T3
Bi-d-p	chem,σ, f		42K7
d $22^y Pb^{210}$ (RaD)			
p $138^d Po^{210}$ (RaF)			
p $4^m Tl^{206}$			47B6

AcC
211
83 128

See next page for Bi212 (ThC)

τ 2.16^m 31IR



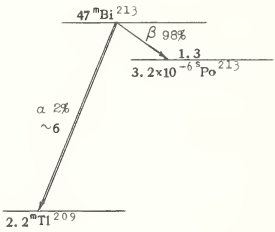
β^-	not observed		
0.32%	from ratio of Po^{211} α's to Bi^{211} α's		31IR
α_1	6.272		38HL
16%			31R2
23%			36R5
α_2	6.618		38HL
84%			31R2
77%			36R5
γ	0.350	a	37S4, 39S12
	0.354	a	25H1
γ/α = 0.14			42S9
Other γ's attributed to AcC			
	0.460		25H1
	0.480		25H1

Proposed cycle scheme for AcC → AcC', AcC" → AcD 46S23

d 38^{m}Pa^{227}, d 2^{m}Ac^{223} } 48G5
p 4.8^{m}Tl^{207}(AcC")
p 5×10^{-3s}Po^{211}(AcC')

(ThC) 213
83 130

τ 47^m 47H2
46 47E3



β^- 98%	~1.3	a	47E3
96%	~1.2	a	47H2
α 2%	5.86	ic	47E3
4%	6.0	ic	47H2
2.0%			49H35

d 0.018^{s}At^{217} 47E3, 47H2
p 3.2×10^{-6s}Po^{213} 47E3, 47H2

Rac
214
83 131

τ 19.7^m 31IR

β^- 99.96% 31IR

1.650	s	~77%	41C4
3.173	s	~23%	41C4
3.15	a		33Sar

For discussion of β energies and %'s see 48F14

α 0.04% 31IR

5.333	s	17%	48C22
5.444	s	55%	34LB
5.466	s	48%	48C22
5.505	s	45%	34LB
5.517	s	37%	48C22

d 26.8^{m}Pb^{214}(RaB)
p 1.47×10^{-4s}Po^{214}(RaC')
p 1.32^{m}Tl^{210}(RaC")

γ hν 34E1 sc	47L24 s	Rel. Intensity 46S23 *	47L24 **
0.426			
0.498			
0.607	0.606	8.9	
0.766		0.88	
0.933		0.90	
1.120	1.120	2.9	1.76
1.238	1.234	0.85	0.41
	1.290		
1.379	1.370	0.86	1.32
1.414	1.414		
	1.520		0.56
	1.620		
	1.690		
1.761	1.761	2.8	2.51
	1.820		3.2
	2.090		
2.193	2.200	1.0	1.0
	2.420		0.34

Proposed cycle scheme for RaC → RaC', RaC" → RaD 46S23

α's from ground and excited states of daughter Po^{214} (RaC')

Energy	Rel. Number	
7.683	10^6	34LB
8.280	0.43	
8.941	0.45	
9.069	22	
9.315	0.38	
9.492	1.35	
9.660	0.35	
9.781	1.06	
9.908	0.36	
10.077	1.67	
10.149	0.38	
10.329	1.12	
10.509	0.23	

* Estimated from data of 34E1 on number of conversion e^-'s per disintegration assuming quadrupole transitions

** Relative intensities of groups indicated from recoil spectrum. Results from conversion e^+'s in good agreement. All transitions appear quadrupole.

ThC
212
83 129

τ 60.5^m 31IR

Proposed level scheme 37S7
$\gamma/\alpha = 4$ 47K12
$e^-/\alpha \geq 0.55$ 49B43, 39F4

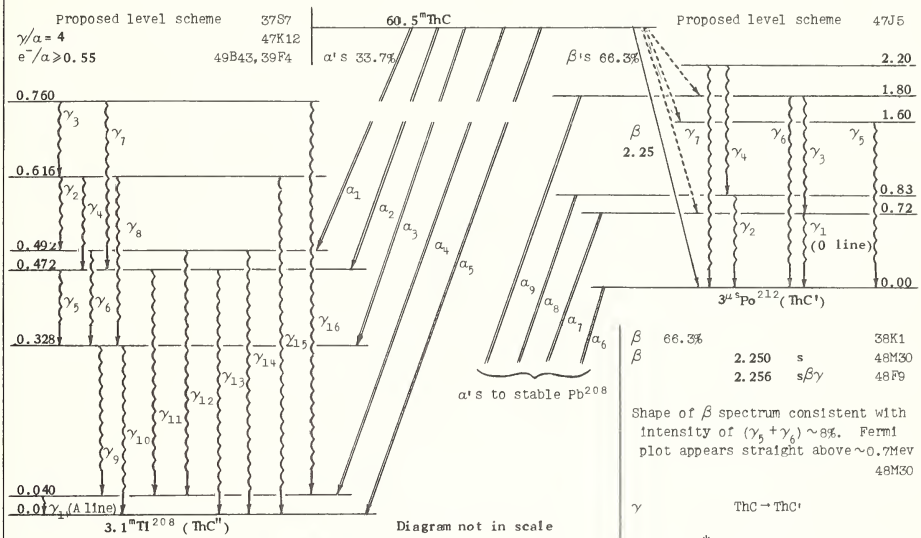


Diagram not in scale

γ	ThC → ThC"	sc	37S7

Following values confirm older work

	$h\nu$	K line inten.*
γ_1 (A line)	0.0398	
γ_2	0.124	<0.05
$\gamma_3, \gamma_4, \gamma_5$	0.144	0.1
γ_6	0.162	0.05
$\gamma_7, \gamma_8, \gamma_9$	0.287	0.2
γ_{10}	0.327	0.07
γ_{11}	0.431	<0.05
γ_{12}	0.451	<0.05
γ_{13}	0.471	<0.05
γ_{14}	0.491	<0.05
γ_{15}	0.616	<0.05
γ_{16} ?	0.719	0.1 ?

Note γ_1 in ThC → ThC'

* Relative to 100 for F line of ThB

α 33.7%				38K1
α_1	5.601	1.10%		34LB
α_2	5.620	0.16%		34LB
α_3	5.762	1.80%		34LB
α_4	6.044	69.8%		34LB
	6.074	~77%		48C21
α_5	6.083	27.2%		34LB
	6.113	~23%		48C21
	ThC' → Pb^{208}			
α_6 (10^6)*	8.776			38HL, 36B5
α_7 (34)*	9.488			38HL, 32R1
α_8	9.600 ?			32R1
α_9 (190)*	10.538			38HL, 32R1
	10.55			48C21

* Relative numbers of α's 34LB

β 66.3%				38K1
β	2.250	s		48M30
	2.256	s	βγ	48F9

Shape of β spectrum consistent with intensity of $(\gamma_5 + \gamma_6) \sim 8\%$. Fermi plot appears straight above ~0.7Mev 48M30

γ		ThC → ThC'			
γ_1	18.5%*	0.72**	s	(0 line)	47J5
		0.719	s		46S23
γ_2	16%*	0.83	s		47J5
		0.779	s		46S23
γ_3	5.5%*	1.03	s		47J5
γ_4	4.5%*	1.34	s		47J5
	1.8%*	1.35	s		47L24
γ_5	7%*	1.61	s		47J5
	5%*	1.60	s		47L24
γ_6	7%*	1.81	s		47J5
	3%*	1.80	s		47L24
		1.793	s		46S23
γ_7		2.20	s		47J5
	2.5%*	2.20	s		47L24
γ		1.50	s		47L24

* % of β branch disintegrations, calculated from recoil electrons and above βα branching ratio

** Note γ_{16} in ThC → ThC"

202				203				204			
84	118			84	119			84	120		
τ	40^m		49K11	τ	37^m		49K11	τ	4^h		49K11
K ~100%			49K11	K			49K11	K ~100%			49K11
α ~0.1%	5.56	ic	49K11	α			49K11	α ~0.1%	5.35	ic	49K11
B1-p			49K11	B1-p-7n			49K11	B1-p-6n			49K11
					p 12^hB1		49K11		p $18^h Pb^{200}$		49K11
	p 2^hB1		49K11		p 52^hPb		49K11		p $12^h B1^{204}$		
									p $68^m Pb^{204}$		

205				206				207			
84	121			84	122			84	123		
τ	1.5^h		49K11	τ	9^d		47T1	τ	5.7^h		47T1
K			49K11	K ~90%			47T1	K ~100%			47T1
				γ	0.8	a	47T1	γ	1.3	a	47T1
				weak	~0.3	a	47T1	L X-ray			47T1
α	5.2	ic	49K11	α ~10%	5.2	ic	47T1	α ~0.01%	5.1	ic	47T1
B1-p-5n			49K11	Pb^{204}-α-2n	chem		47T1	Pb^{206}-α-3n	chem,σ		47T1
Pb-α-3n			49K11								
	p ~14^dB1		49K11		p 6.4^dB1		47T1				

208
84 124

τ	3.0^{y}		49K10
	~3		47T1
α	5.14	ic	47T1
No γ			47T1
Bi-d-3n	chem,σ		47T1
	f		49K10
Pb^{206}-α-2n	chem		47T1
Pb^{207}-α-3n	chem		47T1
Bi-p-2n			46L1
	No daughter activity		47T1
	d $7.0^{h}At^{208}$		49B12
	d $1.7^{h}At^{208}$	chem	49H13
	d $23^{m}Em^{212}$	chem	49H13

209
84 125

τ	$\sim 200^{y}$		49K10
α	4.95		49K10
Bi-d-2n			49K10

RaF 210
84 126

τ	138.3^{d}		49B54
	140		31IR
γ	0.773	s	47S4
	0.8	a	47D1
$\gamma/\alpha = 10^{-5}$			48Z3
α	5.298	s	38HL
	5.303	s	46C6
No α fine structure			48W17
Pb^{208}-α-2n	chem,σ		47T1
Bi-d-n	chem,σ		47T1
	chem,σ, f		40C2,42K7
	f		49K10
	d $5^{d}Bi^{210}$ (RaE)		
	d $8.3^{h}At^{210}$		49K10

AcC' 211
84 127

τ	$5\times10^{-3\,s}$		31IR
α	7.434	s	34LB
Long range α ?			
~0.01%	~9.2		33C3
	d $2.1^{m}Bi^{211}$(AcC)		
	d $7.5^{h}At^{211}$		40C10

ThC' 212
84 128

τ	$3.04\times10^{-7\,s}$		49B9
	3.0×10^{-7}		48H21
	3.4×10^{-7}		48J5
	2.2×10^{-7}		49V1
Levels			Bi^{212}(ThC)
α (10^{6})*	8.776	s	38HL,36B5
Long range α's			
(34)*	9.488		38HL,32R1
	9.600 ?		32R1
(190)*	10.538		38HL,32R1
	10.55		48C21
* Relative numbers of α's			34LB
	d $60.5^{m}Bi^{212}$ (ThC)		
	d $9.3^{m}U^{228}$		49M16

213
84 129

τ	$3.2\times10^{-6\,s}$		47E3
	4.2×10^{-6}		48J5
α	8.336	ic	47E3,48C12
	8.30	ic	47H2
	d $10^{-3\,s}Em^{217}$		49M16
	d $47^{m}Bi^{213}$		47H2,47E3
	p $3.3^{h}Pb^{209}$		47H2,47E3

RaC' 214
84 130

τ 1.47×10^{-4} s 48B14
1.40×10^{-4} 48R8
1.48×10^{-4} 42W4
1.45×10^{-4} 41R6
1.55×10^{-4} 43J1

Levels Bi^{214}(RaC)

α (10^6)* 7.680 s 38HL

Long range α's 34LB

(0.43)*	8.280	(1.06)	9.782
(0.45)	8.941	(0.36)	9.908
(22)	9.069	(1.67)	10.077
(0.38)	9.315	(0.38)	10.149
(1.35)	9.492	(1.12)	10.329
(0.35)	9.660	(0.23)	10.509

9.080 48C22

* Relative numbers of α's 34LB

d 19.7^mBi^{214} (RaC)
d 0.019^sEm^{218} 46S14
p 22^yPb^{210} (RaD)

AcA 215
84 131

τ 1.83×10^{-3} s 42W4

β^- 5×10^{-4}% 44K2

α 7.365 s 34LB

Levels Em^{219}(An)
0.198
0.265
0.389
0.590

d 3.9^sEm^{219} (An)
p 36.1^mPb^{211} (AcB)
p 10^{-4} s At^{215}

ThA 216
84 132

τ 0.158 s 42W4

β^- 0.014% 43K2

α 6.774 s 38HL

d 54^sEm^{220} (Tn)
p 10.6^hPb^{212} (ThB)
p 3×10^{-4} s At^{216}

217
84 133

RaA 218
84 134

τ 3.05^m 31IR

β^- 0.04% 43K4

α 5.998 s 38HL

d 3.8^dEm^{222} (Rn)
p 26.8^mPb^{214} (RaB)
p short At^{218}
p 0.019^sEm^{218} 49W5

$^{\leq 205}_{85}$				$^{\leq 206}_{85}$				$^{207\,?}_{85\quad 122\,?}$			
τ	10^m		49B40	τ	25^m		49B40	τ	1.7^h 1.8		48T6 49B12
K ?			49B40	K ?			49B40	K ?			48T6
α	6.10	ic	49B40	α	5.90	ic	49B40	α	5.76	ic	48T6
Bi-α	chem		49B40	Bi-α	chem		49B40	Bi-α	chem		48T6

$^{208}_{85\quad 123}$								$^{209}_{85\quad 124}$			
τ_1	1.7^h		49H13	τ_2	7.0^h 4.5^h		49B12 48T6	τ	5.7^h		49B12
K 99.5%			49H13	K			49B12, 48T6	K ?			49B12
γ	1.1	a	49H13								
K,L X-rays			49H13								
α ~0.5%	5.65	ic	49H13	α not observed				α	5.65	ic	49B12
				Bi-α	chem		48T6	Bi-α	chem		49B12
	d 19.3^{m}Fr^{212} chem p 3^{y}Po^{208}		49H13 49H13		p 3^{y}Po^{208}		49B12				

210 85 125	211 85 126	212 85 127
τ 8.3^{h} 49K10	τ 7.5^{h} 40C10	τ 0.25^{s} 48W6
K 49K10	K 60% 40C10	
γ, e^{-} 1 a 49K10		
Po K X-ray		
α/K $<10^{-4}$ 49K10	α 5.89 ic 48T6 40% 5.94 a 40C10	α 48W6
Bi-α-3n chem 49K10 threshold ~29 49K10	Bi-α-2n chem 40C10	Bi-α-n 48W6
p 138^{d}Po^{210} 49K10	d 8^{m}Fr^{211} 49H13 p 5x10^{-3}^{s}Po^{211} 40C10	

213 85 128	214 85 129	215 85 130
	τ short 49M16	τ ~10^{-4}^{s} 49M16 short 44K1
	α 8.78 ic 49M16	α 8.00 ic 49M16 8.43 ic 44K1
	d 1.7^{m}Pa^{226} ? 49M16	d 1.8x10^{-3}^{s}Po^{215} (AcA) d 3.9^{s}Em^{219} (An) 44K1 d 2^{m}Ac^{223} 48G5

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216 85 131				217 85 132				218 85 133			
τ	$\sim 3\times10^{-4}$ s		49M16	τ	0.018 s		47H2	τ	1.5 - 2.0 s		49W5
	short		44K1		0.021		47E3				
								β^- 0.1%			49W5
α	7.79	ic	49M16	α	7.00		47H2	α	6.76	ic	44K1
	7.66	ic	44K1		7.02		47E3	99.9%	6.7	ic	49W5
								Not found from Fr separated from Rn			46K6
	d $54^s Em^{220}$ (Tn)		44K1		d $4.8^m Fr^{221}$		47H2, 47E3		d $3.05^m Po^{218}$ (RaA)		49W5
	d $2.9^h Ac^{224}$		48G5		p $47^m Bi^{213}$		47H2, 47E3		d $3.8^d Em^{222}$ (Rn)		44K1

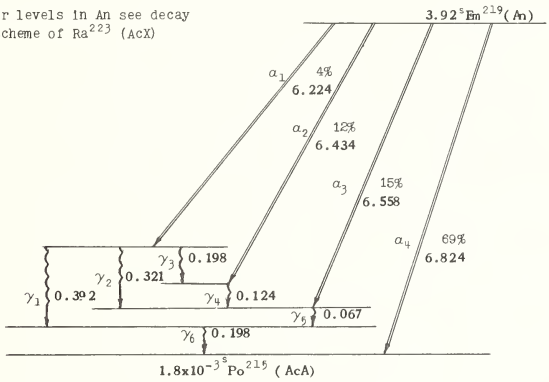
210 ?			211			212		
86			86	125		86	126	
τ	2.3^{h}	49G16				τ	23^{m}	49H13, 49G16
α		49G16				α	6.17	49H13
Th-p		49G16				Th-p		49G16
						d	$19.3^{m}Fr^{212}$	49H13
						p	$3^{y}Po^{208}$	49H13

216			217			218		
86	130		86	131		86	132	
τ	short	49M16	τ	$\sim 10^{-3\,s}$	49M16	τ	0.019^{s}	46S14
							1.3	49W5
α	8.07 ic	49M16	α	7.74 ic	49M16	α	7.12	46S14
d	$9.3^{m}U^{228}$	49M16	d	$58^{m}U^{229}$	49M16	gaseous d	$3.05^{m}Po^{218}$ (RaA)	49W5
						d	$38^{s}Ra^{222}$	46S14

An 219
86 133

τ 3.92^{s} 31IR

For levels in An see decay scheme of Ra^{223} (AcX)



0.198 γ very intense, suggesting another α obscured by AcC α 37S7

α_1	4%	6.224	s	36R5
α_2	12%			36R5
		6.434	s	34LB
α_3	15%			36R5
		6.558	s	34LB
α_4	69%			36R5
		6.824	s	38HL, 34LB
γ's			sc	37S7

γ values in agreement with 37S7 found by crystal spect 40F2

d 11.2^{d}Ra^{223} (AcX)
p 1.8x10^{-3}^{s}Po^{215} (AcA)

Tn 220
86 134

τ 54.5^{s} 31IR

α 6.282 s 38HL

d 3.6^{d}Ra^{224} (ThX)
p 0.16^{s}Po^{216} (ThA)

221
86 135

Rn 222
86 136

τ 3.825^{d} 31IR

α 5.486 s 38HL

$\beta/\alpha < 10^{-6}$ 46K6

d 1622^{y}Ra^{226}
p 3.05^{m}Po^{218} (RaA)

211 87 124	212 87 125	
τ 8^m 49H13	τ 19.3^m 49H13	
K 49H13	K 5e% 49H13	
	α 44% 6.25 ic 49H13	
Th-p chem 49H13	Th-p chem 49H13	
p $7.5^h At^{211}$ 49H13	p $23^m Em^{212}$ 49H13 p $1.7^h At^{208}$ 49H13	

218 87 131			219 87 132			220 87 133		
τ	short	49M16	τ	$\sim 0.02^{s}$	49M16	τ	27.5^{s}	49M16
α	7.85 ic	49M16	α	7.30 ic	49M16	α	6.69 ic	49M16
	d $1.7^{m}Pa^{226}$?	49M16		d $2^{m}Ac^{223}$	48G5		d $2.9^{h}Ac^{224}$	48G5

221 87 134			222 87 135			AcX 223 87 136		
τ	4.8^{m}	47H2	τ	14^{m}	49H13	τ	21^{m}	46P5
	5	47E3						
			β^{-}		49H13	β^{-}	1.20 cc	46P5
						γ	0.095 a	46P5
							0.090 a	44L9
α	6.30	47H2						
	6.31	47E3						
			Th-p	chem	49H13			
	d $10^{d}Ac^{225}$	47H2, 47E3					d $21.7^{y}Ac^{227}$	39P1
	p $0.018^{s}At^{217}$	47H2, 47E3		p $38^{s}Ra^{222}$	49H13		p $11.2^{d}Ra^{223}$ (AcX)	47G17

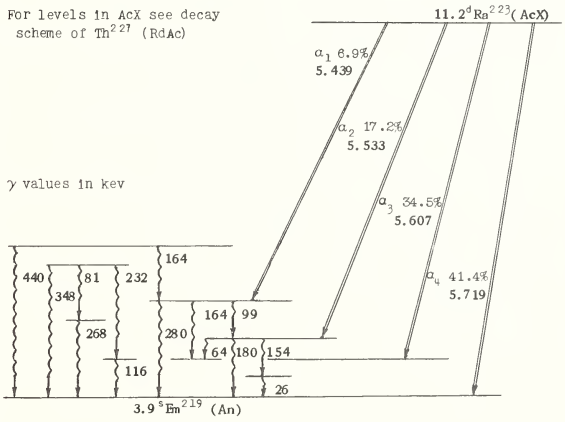
220 88 132	221 88 133	222 88 134
τ short 49M16	τ 31^{s} 49M16	τ 38.0^{s} 46S14
α 7.49 ic 49M16	α 6.71 ic 49M16	α 6.51 ic 46S14
d $9.3^{m}U^{228}$ 49M16	d $58^{m}U^{229}$ 49M16	d $31^{m}Th^{226}$ 46S14 p $0.019^{s}Em^{218}$ 46S14

AcX
223
88 135

τ 11.2^{d} 31IR

For levels in AcX see decay scheme of Th^{227} (RdAc)

γ values in kev



α_1	6.9%	5.439	36R5
α_2	17.2%		36R5
	9.1%	5.533	34LB
α_3	34.5%		36R5
	36.4%	5.607	34LB
α_4	41.4%		36R5
	54.5%	5.719	34LB

γ's (in kev in scheme) sc 37S7

γ's found with cryst spect
144, 155, 180, 270, 340kev. 40F2

d $21^{m}Fr^{223}$ 47G17
d $2.2^{m}Ac^{223}$ 49M16
d $18.6^{d}Th^{227}$ (RdAc)
p $3.9^{s}Em^{219}$ (An)

ThX
224
88 136

τ	3.64^{d}		38L7
Levels	0.0833	Th^{228} (RdTh)	
	0.0868		
α	5.681	s	36B5
	5.66	ic	45C3
4.6%	5.448	s	49R9
0.4%	5.194	s	49R9
γ	~0.250		15V1
No low energy e^-			28M2

d $1.9^{y}Th^{228}$ (RdTh)
d $2.9^{h}Ac^{224}$ 48G5
p $54.5^{s}Em^{220}$ (Tn)

225
88 137

τ	14.8^{d}		47H2
	14		47E3
β^-	~0.2		47H2
	<0.05		47E3
Levels	0.10	?	Th^{229}
	0.20	?	

d $7\times10^{3^{y}}Th^{229}$ 47H2,47E3
p $10^{d}Ac^{225}$ 47H2,47E3

226
88 138

τ	1620^{y}		47K7
	1600		39G5
	1690		35G2(47K7)
	1600		34G3(47K7)
	1590		31IR
Levels	0.068	Th^{230} (Io)	
	~0.190		
α 93.5%	4.795	s	49R8
	4.791	s	34LB
6.9%	4.611	s	49R8
	4.610	s	34LB
γ	0.188		24H1
Probably no additional α fine structure			48W17

d $8.0\times10^{4^{y}}Th^{230}$(Io)
p $3.82^{d}Em^{222}$ (Rn)

227
88 139

β^-			47P9
Ra-n-γ			47P9

p $21^{y}Ac^{227}$ 47P9

$MsTh_1$
228
88 140

τ	6.7^{y}		31IR
β^-	~0.0015	cc	49L2
	0.053		39L14
β^- or e^-	15% 0.0015-0.018		49L2

d $1.39\times10^{10^{y}}Th^{232}$
d $6.13^{h}Ac^{228}$ ($MsTh_2$)

222 89 133	223 89 134	224 89 135
τ short 49M16	τ 2.2^{m} 49M16	τ 2.9^{h} 49M16
	K 0.1% 49M16	K ~90% 49M16
α 6.96 ic 49M16	α 99.9% 6.64 ic 49M16	α ~10% 6.17 48G5
d $1.7^{m}Pa^{226}$? 49M16	d $38^{m}Pa^{227}$ 48G5 p $2.2^{m}Bi^{211}$ (AcC) 48G5 p $11^{d}Ra^{223}$ (AcX) 49M16	d $22^{h}Pa^{228}$ 48G5 p $3.6^{d}Ra^{224}$ (ThX) 48G5 p $27.5^{s}Fr^{220}$ 48G5

225 89 136	226 89 137	227 89 138
τ 10.0^{d} 47H2 10 47E3	τ 22^{h} 48S9	τ 21.7^{y} 44C2 13.5 31IR
	β^{-} 48S9	β^{-} 99% ~0.02 cc 46P5 γ 0.037 a 46P5 α large 43L3 L X-ray 40% 43L3
α 5.80 ic 47H2,47E3		α 1.2% 46P5,47P15 4.94 ic 48G15 4.92 48V3 photographic plate Fine structure reported by 47G9,46P5, but expected accompanying γ of 0.35 not found.
d $1.5^{d}Ac^{229}$ d $7.8^{m}Th^{225}$ 49M16 d $14.8^{d}Ra^{225}$ 47H2,47E3 p $4.8^{m}Fr^{221}$ 47H2,47E3	U-α 48S9 p $31^{m}Th^{226}$ 48S9	For possible levels in Ac^{227} see Pa^{231} d $3.4\times10^{4}{}^{y}Pa^{231}$ p $18.6^{d}Th^{227}$ (RdAc) p $21^{m}Fr^{223}$ (AcK)

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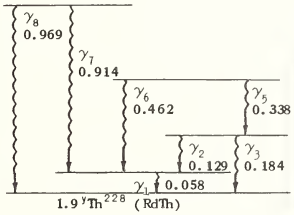
Ms Th_2
228
89 139

τ	6.13^h		31IR
β^-	1.55	s	39L1
	~1.7	cc	38L7
	2.0	a	38F3
γ		sc	24B1



α ?	4.54	a	33G1

Two β groups observed in cloud chamber with ~equal intensity with upper limits 0.060 and 1.5 Evidence for delay 49L2

γ's at 0.333, 0.461, 0.913, 0.967 found from photo electrons s 26T1

γ of 0.318 also found 24B1

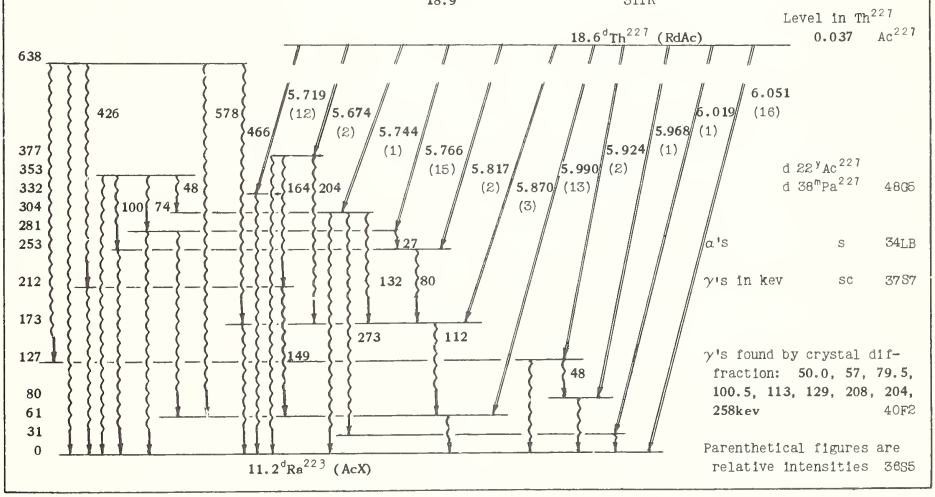
Soft γ's most strongly converted 24B1

d 6.7^{y}Ra^{228} ($MsTh_1$)
p 1.9^{y}Th^{228} (RdTh)

224 90 134	225 90 135	226 90 136
τ short 49M16	τ 7.8^{m} 49M16	τ 30.9^{m} 46S14
	K ~10% 49M16	
α 7.20 ic 49M16	α ~90% 6.57 ic 49M16	α 6.30 ic 46S14
d $9.3^{m}U^{228}$ 49M16	d $58^{m}U^{229}$ 49M16 p $10^{d}Ac^{225}$ 49M16	d $21^{d}U^{230}$ chem 46S14 p $38^{s}Ra^{222}$ 46S14

RdAc
227
90 137

τ 18.6^{d} 47P14
18.9 31IR



RdTh 228 (90 138)

τ	1.90^{y}		31IR
α 72%	5.423 s	possibly double	49R2
28%	5.338 s		49R2
83%	5.418 s		34LB
17%	5.333 s		34LB
Corroborating results			48C21
γ	0.0833	not K_α lines of Ra	41S10
	0.0868		41S10
d $6.1^{h}Ac^{228}$ ($MsTh_2$)			
d $22^{h}Pa^{228}$			48G5
p $3.6^{d}Ra^{224}$ (ThX)			

229 (90 139)

τ	$7{,}000^{y}$		47H2
	~10,000		47E3
Levels	0.040 ?		U^{233}
	0.080 ?		
	0.31 ?		
α	5.02		48J18
	4.94		48J18
	4.85		48J18
~10%	5.05		46H20
~20%	4.95		46H20
~70%	4.85		46H20
d $1.62\times10^{5\,y}U^{233}$			47H2, 47E3
p $14.8^{d}Ra^{225}$			47H2, 47E3

Io 230 (90 140)

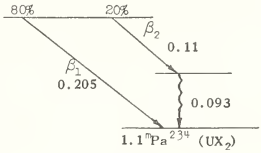
τ	$8.0\times10^{4\,y}$		46H21
	8.3×10^{4}		31IR
Level	0.94 ?		Pa^{230}
α ~75%	4.682 s		48R5
~25%	4.612 s		48R5
	4.509 ? s		48R5
	4.66		44C9
γ	0.068 a		39W6
	0.190 a		39W6
~11%	0.068 a	$\alpha = 14$	48T12, 48C20
~1%	0.15-0.20 a	$\alpha = 5$	48C20, 48T12, 48C20
$e^{-}/\alpha = 0.1$			48T12, 49A9
L X-rays/$\alpha = 0.1$			49R10, 48C20
d $17.7^{d}Pa^{230}$			
d $2.67\times10^{5\,y}U^{234}$			
p $1.62\times10^{3\,y}Ra^{226}$			

UY 231 (90 141)

τ	25.65^{h}		48J17
	25.5		49K9
	24.6		31IR
β^{-}	0.21 a		49K9
	~0.2 a		37E1, 48J15
γ >80%	0.035 a	$\alpha = 4.5$, $\tau < 1^{\mu s}$	49K9
	0.035 a		48J15
	0.065 a		48J15
Level	0.16		U^{235}
d $8.8\times10^{8\,y}U^{235}$			
p $3.43\times10^{4\,y}Pa^{231}$			

232 (90 142)

τ	$1.39\times10^{10\,y}$		38K1
α	3.98 ic		45C3
	4.20 ic		37S5
σ's			
(9Mev d,p)$23^{m}Th$		6.3mb	42K7
p $6.7^{y}Ra^{228}$ ($MsTh_1$)			

$^{233}_{90}$ $_{143}$				UX_1 $^{234}_{90}$ $_{144}$				
τ	23.5^m		47S5	τ	24.10^d		48K23	
	23.0		41G3		24.1		39S11	
β^-	1.2	a	42S6					
No γ			42S6					
				β_1^- 80%	0.205	s	46B12	
					0.190	s	46J1	
					0.2	a	38F2	
				β_2^- 20%	0.11	s	46B12	
					0.1	a	38F2	
				γ	0.093	sc	46B12	
					α_L = 0.34		46B12	
Th-n-γ			38M4, 41S9, 41G3		0.092	sc	46J1	
Th-d-p			42G4					
	chem, σ, f		42K7	γ 4.5%	0.180	a	46B12	
				not assigned				
p 27.4^{d}Pa^{233}				d 4.5x10^9^{y}U^{238}				

226
91 135

τ	1.7^{m}		49M16
α	6.81	ic	49M16
Th-d-8n	chem		49M16

227
91 136

τ	38^{m}		49M16
K 16%			49M16
α 84%	6.46	ic	49M16
Th-α-7n	chem		48G5
d $53^{m}Np^{231}$			48G12
p $18.6^{d}Th^{227}$ (RdAc)			48G5
p $2.2^{m}Bi^{211}$(AcC)			48G5
p $4.8^{m}Tl^{207}$ (AcC")			48G5

228
91 137

τ	22^{h}		49M16
K 98%			48G5
α 2%	6.09	ic	49M16
Th-d-6n	chem		48G5
p $61^{m}Bi^{212}$ (ThC)			48G5
p $1.9^{y}Th^{228}$ (RdTh)			48G5

229
91 138

τ	1.5^{d}		48H9
	1.4		46H11
K 99%			48M24
α 1%	5.69	ic	48M24
	5.66	ic	48H9
Th^{230}-d-3n	chem		46H11
p $10^{d}Ac^{229}$			46H11

230
91 139

τ	17.7^{d}		4602
	17.0		46S14
K 90%			48S10
β^{-}	~1.1	a	4602
γ	0.94	a	4602
Th^{230}-d-2n	chem		46H11
Th-d-4n			46S14
Pa-d-p2n			4602
Pa-α-αn			4602
U^{233}-d-αn			46H9
p $21^{d}U^{230}$			46S14

231
91 140

τ	$34,300^{y}$		48V2
	32,000		30G1
I	3/2	S	34S4
Levels	0.035		Th^{231}
	0.065		
α 11%	5.042	s	49C25
47%	5.002	s	49C25
25%	4.938	s	49C25
3%	4.838	s	49C25
11%	4.720	s	49C25
1-3%	4.660	s	49C25
~85%	5.00	ic	46T2
~15%	4.69	ic	46T2
	4.72	ic	46T2
γ	0.095	s	28M1,42H1
	0.294	s	28M1,42H1
	0.323	s	28M1,42H1
e^{-}	24, 36, 46, 75kev		49T15
e^{-}	27		49S35
L X-ray			49S35
d $25^{h}Th^{231}$ (UY)			
p $21.7^{y}Ac^{227}$			

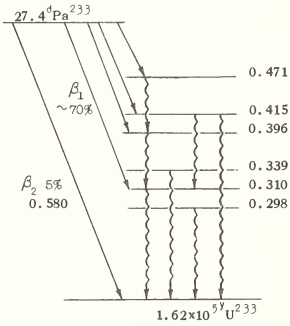
232
91 141

τ	1.32^d		48J10
	1.4		4602
β^-	0.28	a	48J16
γ	~0.23	a	48J16
	1.05	a	48J16
Th-d-2n	chem		42G4, 46S14
Th-α-p3n	chem		46S14
Pa-d-p			4602
	p $70^y U^{232}$		42G4

233
91 142

τ	27.4^d		41G3
β^-	0.23	s	42H1, 41H6
	~0.2	s	47L6
γ	0.084	sc	47L6
	0.298	sc	
	0.309	sc	
	0.337	sc	
Th-d-n	chem		42G4, 46S14
Th-α-p2n	chem		46S14
	d $23.5^m Th^{233}$		38M4, 41S9, 41G3
	d $2.2 \times 10^6{}^y Np^{237}$		47H2
	p $1.62 \times 10^5{}^y U^{233}$		47S5

Proposed decay scheme 50E1



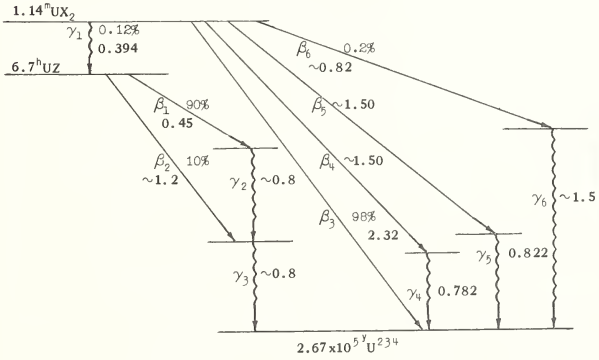
Possibly γ's of 0.396 and 0.471 coincidences shown by two spectrometers 50E1

234
91 143

UX_2

τ_1	1.14^m	31IR
	1.22	48H6

Proposed decay scheme 45B5, 47B17



Level in UX_2
0.093 $Th^{234}(UX_1)$

UX_2 daughter of $24.1^d Th^{234}(UX_1)$
See decay scheme of Th^{234}

UZ

τ_2	6.7^h	31IR

$1.14^m UX_2$

β_2^-	98%	2.32	s	45B5
β_4^-, β_5^-	~2%	~1.50		47B17
β_6^-	0.2%	~0.82		47B17
γ_1	0.12%	0.394	s	45B5
		K/L < 0.3		
		α_{L+M} ~1		
	0.15%			38F2
γ_4, γ_5		0.782, 0.822	s	43B4
		$\alpha_K = 0.36$, $\alpha_L = 0.10$		43B4
γ_6		~1.5		47B17

$6.7^h UZ$

β_1^-	90%	0.45	s	45B5
$\beta\gamma$ coincidences				
β_2^-	10%	~1.2	s	
γ_2, γ_3		~0.8	a	45B5
		α small		
$\gamma/\beta = 1.8$				
No $\gamma\gamma$ angular correlation				

228
92 136

τ	9.3^{m}		49M16
K ~20%			49M16
α ~80%	6.72	ic	49M16
Th-α-8n			49M16
p Po^{212} (ThC')			49M16
p $22^{h}Pa^{228}$			49M16

229
92 137

τ	58^{m}		49M16
K ~84%			49M16
α ~16%	6.42	ic	49M16
Th-α-7n			49M16
p Po^{213}			49M16
p $1.5^{d}Pa^{229}$			49M16

230
92 138

τ	20.8^{d}		46S14
α	5.86	ic	46S14
	5.85	ic	46J4
Th-α-6n			46S14
p Po^{214} (RaC')			46S14
d $18^{d}Pa^{230}$		chem	46S14

231
92 139

τ	4.2^{d}		4602
K			4602
K,L X-rays			49C6
No γ			49C6
α 0.05%			49C6
Pa-d-2n			4602
Pa-α-p3n			4602
p $18.6^{d}Th^{227}$ (RdAc)			49C6
p $3.43\times10^{4y}Pa^{231}$			49C6

232
92 140

τ	70^{y}		48J8
	~30		42G4
Levels	~0.23 ?		Pa^{232}
	1.05 ?		
α	5.31	a	48J19
	5.27		44K8
Th-α-4n			48N4
Pa-d-n			4602
Pa-α-p2n			4602
d $1.3^{d}Pa^{232}$			42G4,4602
d $2.7^{y}Pu^{236}$			48J8
p $1.9^{y}Th^{228}$ (RdTh)			42G4

233
92 141

τ	1.62×10^{5y}		46H10
	1.63×10^{5}		45L7
Levels	0.084	?	Pa^{233}
	0.298	?	
	0.309	?	
	0.337	?	
α	4.823	ic	48C12
	4.825	ic	47E3
	4.80	a	43C5
Complexity in α's not detected			47S19
γ	0.040	a	47S19
0.8%	0.080	a, α~8	47S19
0.1%	0.31	a, α~3	47S19
L X-ray			47S19
	σ's		
(44Mev α,n) Pu^{236}	0.5mb		48P10
(44Mev α,3n) Pu^{234}	1mb		48P10
(44Mev α,p2n) Np^{234}	0.2mb		48P10
d $27.4^{d}Pa^{233}$			47S5,47S19
p $7000^{y}Th^{229}$			47H2,47E3

234
92 142

	0.00580% (wt)		49G18
	0.00548 (wt)		49K26
	0.0050 (atom)		46C2
	0.0058 (atom)		39N3
τ	2.67×10^{5} y		49G18
	2.52×10^{5}		49K26
	2.35×10^{5}		46C2
	2.69×10^{5}		39N3
	2.3×10^{5}		49B41
Levels	0.78		Pa^{234}
	0.82		Pa^{234}
	1.5		Pa^{234}
	~1.8		Np^{234}, Pa^{234}
α	4.763	ic	44C9
	4.76	ic	39S13
	4.78	ic	47A6
L X-ray 33%			47M30
L X-ray 25% attributed to highly converted γ			49S35

d $92^{y}Pu^{238}$
d $1.1^{m}Pa^{234}$ (UX_2)
d $6.7^{h}Pa^{234}$ (UZ)
p 8×10^{4} y Th^{230} (Io)

235
92 143

	0.71%		39N3
τ	8.8×10^{8} y		49K26
	8.91×10^{8}		44C9
	7.07×10^{8}		39N3, 41K8
I	5/2 or 7/2 S		47A5, 45T5
Levels	0.2 ?		Pu^{239}
	0.4 ?		
α 20%	4.56	ic	44C9
80%	4.396	ic	44C9
	4.39	ic	49B41
γ ~100%	0.162	a	49M37
	0.187	a	46S20

p $26^{h}Th^{231}$ (UY)

236
92 144

237
92 145

τ	6.63^{d}		49M43
	6.8		50b16, 42W5
	6.9		50e10
β^- complex ?	~0.23	s	49M43
	0.17	a	44A1
	0.22	a	44A1
complex	~0.25	a	50e10
γ	0.057	s	49M43
	0.204	s	49M43
	0.260	s	49M43
	0.05	a	50e10
	0.22	a	50e10
	0.40	a	50e10
βe^-, $\gamma\gamma$, and $\beta\gamma$ coincidences			50e10
Np X-ray			50e10
U-n-2n			42W5, 44A1
U-α-an			48J8

d $10^{y}Pu^{241}$ 48S5, 45K9
p 2.2×10^{6} y Np^{237} 48W4

238
92 146

	99.28%		39N3
τ	4.498×10^{9} y		49K26, 44C9
	4.51×10^{9}		39N3, 41K8
τ for double β decay	$>6\times10^{18}$ y		49L18
α	4.180	ic	44C9
	4.18	ic	47A6
	4.21	ic	39S13
	σ's		
(9Mev d,p) $23.5^{m}U$	5.1mb		42K7

p $24^{d}Th^{234}$ (UX_1)

239
92 147

τ	23.5^{m}		47F5
	23.2		42W6
	23.54		43M10
$23.5^{m}U^{239}$			
	1.12	s	48S14
	1.20	a	47F5
	1.2	a	42M7, 42W6
	0.073	s	47S27, 48S14
	α = 0.19		48S14
	0.076	a	47F5
$2.33^{d}Np^{239}$			
β of 2.06 reported by 47S27 not confirmed			47F11
γ of 0.92 assumed to be in cascade with 0.073γ			47S27, 48S14
Second γ also found, but in only 10% of disintegrations			47F11
U-n-γ			37H5, 39I1, 42S4
U-d-p	chem, σ		42K7

p $2.33^{d}Np^{239}$

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231 93 138			
τ	53^{m}		48G12
K			48G12
α	6.2	ic	48G12
U^{235}-d-6n U^{233}-d-4n U-d-9n			48G12
p $38^{m}Pa^{227}$			48G12

232 93 139			

233 93 140			
τ	35^{m}		49M39
K			49M39

234 93 141			
τ	4.40^{d}		46H9
	4.5		48J8
K			46H9, 46J8
γ	1.9	a	46H9
	1.8		48J8
X-ray			48J8
U^{233}-d-n			46H9
U^{235}-d-3n			48J8
U^{235}-α-p4n			48J8
U^{233}-α-p2n			46H9
U^{235}-p-2n			46G13

235 93 142			
τ	435^{d}		48J12
	400		48J8
K			48J8
No γ ?			48J8
α ~0.1%	5.06	ic	48J12
U^{235}-d-2n			48J8
U^{235}-α-p3n			48J8
U^{233}-α-pn			46H9

236 93 143			
τ	22^{h}		48J8
β^{-}	0.5	a	48M25
γ			48J8
U^{235}-d-n U^{238}-d-4n U^{235}-α-p2n			48J8
U^{233}-α-p			46H9
Np-d-t			48J9
Np-α-αn			48J9
p $2.7^{y}Pu^{236}$			48J8

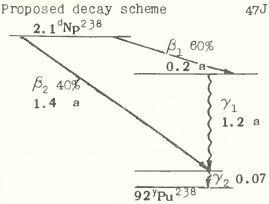
237
93 144

τ	2.2×10^{6} y		48M23, 48M16
	3×10^{6}		48W4
I	5/2	S	48T8
α	4.77	ic	48G13
	4.72	a	47L9
	d $6.8^{d}U^{237}$		48W4
	p $27^{d}Pa^{233}$		48SP

238
93 145

τ	2.10^{d}		47J3
	2.0		42S7

Proposed decay scheme 47J3

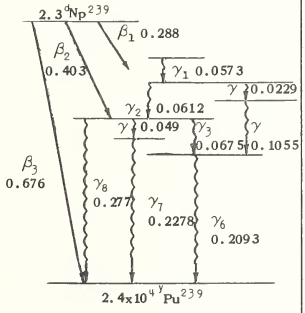


γ_1	1.2		47J3
	$\alpha = 0.018$		
γ_2	0.075		47J3
	almost complete L conversion		
Coincidence measurements			47J3
Np-d-p			48J9
U^{235}-α-p			48J8
U^{238}-α-p3n			48J8
U-d-2n			46S3, 42K6
Np-n-γ			45J2
	d $400^{y}Am^{242}$		48S5
	p $92^{y}Pu^{238}$		46S4

239
93 146

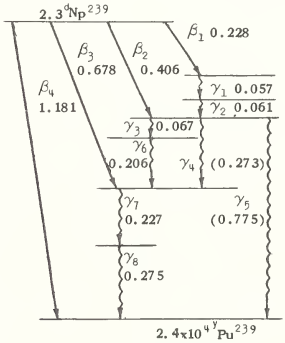
τ	2.33^{d}		42W6
	2.31		46P11
	2.3		40M2

Proposed decay scheme 49K25
β and γ values s 44F11



U-d-n 48J8, 46S3
d $23.5^{m}U^{239}$ 40M2, 42S4
p 2.4×10^{4} $^{y}Pu^{239}$ 46K2

Proposed decay scheme, β and γ values s 48S14



γ_1	0.057	$\alpha = 0.33$	48S14
γ_2	0.061	$\alpha = 0.33$	48S14
γ_3	0.067	$\alpha = 0.33$	48S14
γ_6	0.206	$\alpha = 0.22$	48S14
	0.208		46P11
	0.209		44F11
γ_7	0.227	$\alpha = 0.41$	48S14
	0.226		46P11
	0.228		44F11
γ_8	0.275	$\alpha = 0.19$	48S14
	0.276		46P11
	0.277		44F11
γ	0.5	a	48S14
γ_4 and γ_5 hypothetical			48S14
Other β values			46F6, 40M2, 45H12

232 94 138	233 94 139	234 94 140
τ 22^m 48J14		τ $\sim 8.5^h$ 48P10 8 46H9 K $\sim 99\%$ 48P10
α 6.6 ic 48J14		α $< 1\%$ 6.2 ic 48P10 6.0 ic 46H9
U^{235}-α-7n 48J14		U^{233}-α-3n 46H9, 48P10
p $9.3^m U^{228}$ 48J14		p $21^d U^{230}$ 48P10

235 94 141	236 94 142	237 94 143
	τ 2.7^y 48J8	τ 40^d 48J9 K 48J9 No γ 48J9
	α 5.75 ic 48G13 5.7 ic 48J8	
	U^{235}-α-3n 48J8 U^{233}-α-n 46H9, 48P10 Np-d-3n 48J9	U^{235}-α-2n 48J8 U^{238}-α-5n 48J8 Np-d-2n 48J8, 48J9 Np-p-n 46S26
	d $22^h Np^{236}$ 48J8 d $27^d Cm^{240}$ 48S4	

238 94 144				239 94 145				240 94 146			
τ	92^y		48S4	τ	$2.41\times10^4{}^y$		47S6	τ	$\sim6000^y$		48J8
	89		47J2		2.44×10^4		46W4				
	77		47J3								
γ <2%			42F1	γ weak	0.2	a	45S16				
					0.42	a	45S16				
					0.05	a	44G3				
				weak	0.3	a	44G3				
α	5.493	ic	48J2	α	5.159	ic	48C12	α	5.1	ic	48J8
	5.51	a	47C3		5.140	ic	48J2				
	5.4	a	42F1		5.15	a	47C3				
U^{235}-α-n			48J8					U-α-2n			48J8
U^{238}-α-4n			48J8								
Np-d-n			48J9								
U^{238}-d-2n			42F1								
d $150^d Cm^{242}$			48S4	d $2.3^d Np^{239}$			46K2				
d $2^d Np^{238}$			46S4, 42K6								

241 94 147			
τ	$\sim10^y$		48S5
β^-	0.01-0.02	a	48S5
α			45K2, 48S5
0.002%			47S18
ms			46B17
U-α-n			48S5, 48J8
p $490^y Am^{241}$			48S5
p $6.6^d U^{237}$			45K2, 48S5

238 95 143			239 95 144			240 95 145		
τ	1.5^h	48J11	τ	12^h	48S5	τ	50^h	48S5
							53	48J11
K ?		48J11	K ~100%		48S5	K		48S5
			γ ~60%	0.285 a	48S5	γ ~100%	~1.3 a	48S5
				α~0.5	48S5		α~0.06	48S5
			Pu K,L X-rays		48S5	Pu K,L X-rays		48S5
			α ~0.1%	5.77	48J11			
Pu-d-3n		48J11	Pu-d-2n	chem	48S5	Pu-d-n	chem	48S5
			Np-α-2n	chem	48S5	Np-α-n	chem	48S5
			Pu-p-n		48J11			

241 95 146			242 95 147					
τ	490^y	48C17	τ_1	~16^h	48A6	τ_2	~400^y	48T5
	470	49Y3		17	48S5		~600	48S5
	510	48C15						
			β^-	1.0	48A6	β^-	~0.5	48S5
				0.8	48S5			
α 100%	5.45 ic	48S5				α ~0.2%		48S5
	5.48 ic	48G13						
γ ~60%	0.062 a	48S5						
Np L X-ray		48S5						
X/α = 1		48S5						
			Am-n-γ		48A6, 48S5	Am-n-γ		48S5
	d $10^y Pu^{241}$	48S5		p $150^d Cm^{242}$	48S4, 48A6		p $150^d Cm^{242}$	48S5
							p $2^d Np^{238}$	48S5

238 96 142				239 96 143				240 96 144			
τ	$\sim 2.5^{h}$		48S11					τ	26.8^{d}		48S4
α	6.50	ic	48S11					α	6.26 6.3	ic ic	48G13 48S4
Pu-α-5n			48S11					Pu-α-3n	chem		48S4
								p Pu^{236}			48S4

241 96 145				242 96 146			
τ	55^{d}		48S4	τ	150^{d}		48S4
K			48S4				
				α	6.08 6.1	ic	48G13 48S4
Pu-α-2n	chem		48S4	Pu-α-n	chem		48S4
				d 16^{h} and 400^{y} Am^{242},			48S4, 48A6
				p Pu^{238}			48S4

	243 ? 97 146 ?			
	τ	4.6^h		50T1
	K ~100%			50T1
	α ~0.1%	6.72 6.55 6.20	30% 53% 17%	50T1
	$Am^{241} \rightarrow \alpha - 2n$			50T1

	244 ? 98 146 ?	
	τ ~45^{m} 50T2 K 50T2 α 7.1 50T2 Cm^{242}-α-2n 50T2	

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31IR International Radium Standard Commission Report, M. Curie, A. Debierne, A. S. Eve, H. Geiger, O. Hahn, S. C. Lind, S. Meyer, E. Rutherford, E. Schweidler, Rev. Modern Phys. **3**, 427 (1931); and Physik. Zeits. **32**, 569 (1931).

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The abbreviations used for names of journals are in most cases self explanatory. For journals containing a good deal of nuclear data the abbreviations are the same as those listed in Nucleonics **2**, #5, Part 2. These abbreviations do not differ very much from those used in Physics Abstracts or Chemical Abstracts. For journals not on this list, the abbreviations of Physics Abstracts have been used.

In a number of cases unclassified or declassified data have been reported from work done on Atomic Energy Commission projects. Often it has been possible to give a reference for such results to papers which are generally available. But in a number of instances the experimenters have not published the details of their work in the open literature. Their results, therefore, cannot have the authority of work which has been laid open to general study and criticism. But since the measurements do carry some weight, they have been listed in the table wherever they are not completely superseded by open literature results. Project report numbers are given in the references for the benefit of those who have access to project libraries.

The following abbreviations have been used:

AECD Atomic Energy Commission Declassified.
AECU Atomic Energy Commission Unclassified.
MDDC Manhattan District Declassified.
ANL Argonne National Laboratory.
BNL Brookhaven National Laboratory.
CUD Columbia University.
LA Los Alamos.
ISC Iowa State College.
UCRL University of California Radiation Laboratory.
Y Y-12 Plant, Carbide and Carbon Chemicals Corporation.
AERE Atomic Energy Research Establishment (British).
CR Chalk River (Canadian).

Designations such as CC (Chicago Chemistry) or Mon P (Monsanto Physics) are no longer in current use.

NSA Nuclear Science Abstracts. Issued by United States Atomic Commission, Technical Information Division, Oak Ridge, Tennessee.

NNES National Nuclear Energy Series, Manhattan Project Technical Section, Division IV, Plutonium Project Record. The three volumes to which references are given are 9, 14B, and 17B. Volume 9, on the fission products, will be issued during 1950. Volume 14B, *The Transuranium Elements*, appeared in 1949. Volume 17B which will be classified will appear early in 1951.

After July 1, 1950 declassified and unclassified documents of the Atomic Energy Commission which are for sale can be obtained from the Office of Technical Services of the U. S. Department of Commerce, Washington 25, D. C. A list of such documents will be supplied on request by the Technical Information Division of the Atomic Energy Commission, P. O. Box E, Oak Ridge, Tennessee, or by the Office of Technical Services. Some documents which are not for sale can be secured by government agencies on application to the Technical Information Division at the above address.

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